Cooccurrence Restrictions on Consonants in Some Polynesian Languages

Cooccurrence Restrictions on Consonants in Some Polynesian Languages

Noriko Kawasaki

University of Massachusetts, Amherst

1. Introduction

Mester (1986) proposes explaining certain cooccurrence restrictions on root segments in Javanese and some other languages by the Obligatory Contour Principle (OCP) and dependency relationships among segmental features in these languages. The present paper examines the cooccurrence restrictions on consonants in some Polynesian languages reported by Krupa (1966, 1968, 1971), and considers some of their implications.

2. Mester (1986)

The basic idea of Mester's (1986) analysis of Javanese is as follows.

The Obligatory Contour Principle (OCP), discussed in Leben (1973), McCarthy (1986), and references cited there, prohibits sequences of two or more identical feature specifications. For example, suppose there are two features, a and b. The OCP allows the structures (1abc), but rules out the structures (1de).

(1) a. 

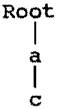
b. 

c. 

d. 

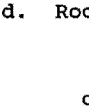
e. 

(I follow Mohanan (1983), Clements (1985) and Sagey (1986), and use the term "Root" for the node that dominates all the melodic features.) Suppose further that there are two other features, c and d, which are dependent on features a and b. This means that either a or b must intervene between a root node and a node for c or d, as shown in (2).

(2) a. 

b. 

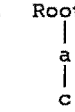
c. 

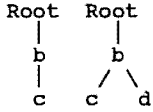
d. 

These structures each represent a sequence of two segments that have the following specifications.

(3)	The first segment		The second segment	
	Dominant Feature	Dependent Feature(s)	Dominant Feature	Dependent Feature(s)
a. (2a)	a	c	b	d
b. (2b)	a	c	b	c
c. (2c)	a	d	a	d
d. (2d)	a	c & d	a	c & d

(3ab) show that if the two segments have different specifications for dominant features (a and b in this case), they may or may not share specifications for dependent features (c and d here). In (3cd), the two segments share specifications for both dominant features and dependent features. Notice that the following structures violate the OCP, because they have sequences of identical specifications for dominant features:

(4) a. 

b. 

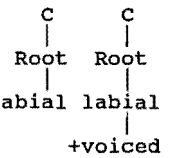
This means that there is no way to represent sequences as in (5), where the two adjacent segments agree in dominant features but not in dependent features.

(5)	The first segment		The second segment	
	Dominant Feature	Dependent Feature	Dominant Feature	Dependent Feature(s)
a.	a	c	a	d
b.	b	c	b	c & d

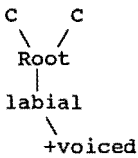
Thus, the hypothesis that c and d are dependent on a and b in a given language predicts that one will not find sequences like (5ab) in that language.

Javanese exhibits dissociations among non-identical consonants with the same place of articulation. Mester (1986) treats place specification as choice among the articulator features [labial], [coronal] and [dorsal], along with Sagey (1986) and other works cited there, and explains these dissociations by assuming that features like [nasal] and [voiced] are dependent on place features in this language. For example, the number of words that contain both p and b are extremely low in Javanese compared with the expected frequency of this combination calculated from the total frequencies of these segments. Mester proposes that this dissociation follows from the dependency relation between place features and voicing features in Javanese: The combination of p and b, for example, is not possible in this language, because the structure (6a) below violates the OCP on the place tier. The structure (6b) represents a sequence of two voiced labials, and does not represent a sequence of p and b.

(6) a.

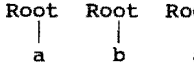


b.



The OCP does not rule out a sequence of two identical specifications, if another feature specification intervenes between the two as in (7).

(7)



Suppose we find dissociations between two consonants sharing the place of articulation in CVCV structure. In order for the OCP to rule out such combinations, vowels must not have place features on the same tier as consonants at least underlyingly.

The dissociations among consonants in Javanese, however, are not complete. There are a small number of morphemes that contain prohibited combinations such as b - p. Mester (1986:121-2) notices the possibility that such exceptional morphemes have feature configurations that are different from those of other morphemes. For example, he suggests that the exceptional morpheme bapa could have the feature [+voiced] directly linked to the Root node (his "core"), rather than to the labial node as in other morphemes of the language. (We will discuss this possibility further in Section 7.) If this is the case, the proposed analysis of the dissociations does not exclude morphemes of the forms like pVbV as absolutely ungrammatical, but it predicts that such morphemes are marked and therefore rare.

Note that the OCP does not rule out (2cd), where the two segments share both the dominant and the dependent features. In Javanese, for example, no significant dissociations are observed between two identical segments (except for /r/-/r/ and /l/-/l/). If a language has, in addition to the OCP, a filter that rules out a single dominant node linked to two or more Root nodes, (2cd) will also be excluded. This will result in dissociation among all segments sharing dominant features.

3. Dissociation among consonants in some Polynesian languages

Krupa (1966, 1971) classifies consonants in some Polynesian languages into three groups according to their place of articulation. The three groups are: F (front: labial consonants), M (middle: consonants ranging from alveolar to palatal) and B (back: velar consonants and laryngeals). He examines cooccurrence restrictions among the three groups within root morphemes in these languages, which have (C)V(C)V(C) structure.

Krupa (1971) reports the results for Easter Island, Hawaiian, Tahitian, Tuamotuan, Rarotongan, Maori, Ceremonial Samoan, and Tongan. Dissociations among consonants in these languages are summarized in (8).

(8) (i) Significant dissociations are found in F-F combinations in all the languages except Easter Island.[1]
(ii) Significant dissociations are found in M-M combinations in all the languages except Easter Island and Hawaiian.
(iii) (i) and (ii) are the only significant dissociations of consonants that are observed. Especially, no significant dissociations are found in B-B combinations in these languages.

Krupa (1966) reports on Hawaiian, Tuamotuan, Maori, Fijian, Proto-Polynesian, and Proto-Austronesian. (9) summarizes dissociations among consonants in these languages.

(9) (i) Significant dissociations are found in F-F combinations in all the languages.
(ii) Significant dissociations are found in M-M combinations in all the languages except Hawaiian.
(iii) Significant dissociations are found in B-B combinations in Fijian and Proto-Austronesian.
(iv) (i) - (iii) are the only dissociations of consonants that are observed.

In general, significant dissociations are found in combinations of consonants with the same place of

---

[1] Unfortunately, I do not have enough data to say anything about Easter Island in the present paper.

articulation, but the dissociations are less complete in some languages. This raises three questions:

(10)(i) Can the OCP and the dependency relationships among features explain the general tendency of dissociations, and if so, how?
(ii) Why are there no significant dissociations found in B-B combinations except in Fijian and Proto-Austronesian?
(iii) Why are there no significant dissociations found in M-M combinations in Easter Island and Hawaiian?

To answer these questions, it is necessary to look into each language in more detail. We will consider these problems in the following sections.

4. Maori

4.1. The data

Krupa (1968) provides a more detailed report on the cooccurrences among consonants in Maori (C)V(C)V root morphemes. This language has three voiceless stops (/p/, /t/, /k/), three nasals (/m/, /n/, /ŋ/), one liquid (/r/), and two continuants (/w/, /wh/). His table 8 is repeated as Table 1 in Appendix.

I calculated the expected frequency and the chi-square value for each cell in Table 1, using the same formulas (11) as in Mester (1986).

(11) $E_{ij} = (N_i \times N_j) / N$

$X^2_{ij} = (O_{ij} - E_{ij})^2 / E_{ij}$

where

E_{ij}: expected frequency in the cell on the i-th column and on the j-th row
N_i: total of the i-th column
N_j: total of the j-th row
N: grand total
X^2_{ij}: chi-square value for the cell on the i-th column and on the j-th row
O_{ij}: observed frequency for the cell on the i-th column and on the j-th row

/w/ and /wh/ are lumped together, because they are low

in frequency in general. The number of cells with the expected frequency lower than 5 ($E \leq 5$) is 4 out of 121 cells (3.31%). The results are given in Tables 2 and 3 in Appendix. Where $X^2 > 3.84$, the observed frequency deviates from the expected frequency significantly at the 0.05 level (on one degree of freedom). The X^2-value is in bold letters where significant dissociation or association was observed.

Table 3 provides three generalizations.

(12) (i) Significant dissociations are found around but not on the diagonal line. That is, significant dissociations are found in combinations of non-identical segments with the same place of articulation, but no significant dissociations are found in combinations of identical segments.
(ii) No significant dissociations are found in combinations involving /t/.
(iii) Significant dissociations are found between the two velars, but not between velars and /h/.

(12iii) suggests that the absence of dissociation effects in B-B combinations reported in Krupa (1968, 1971) has resulted from an inappropriate classification of consonants, where he groups /h/ along with velars. We will return to this in Section 5.

4.2. Labials and Dorsals

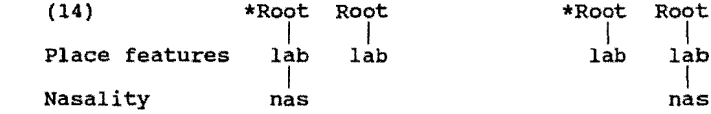
Let us first consider how the generalization in (12i) on labials and dorsals can be explained along the line of Mester (1986). Suppose:

(13) (i) Labial consonants (/m/, /p/, /w/, and /wh/: We will return to /w/ and /wh/ in 4.4.) have the place feature [labial], and dorsal consonants (/k/ and /ŋ/) have the place feature [dorsal].
(ii) The feature for nasality is dependent on place features.

It follows, for example, that mVpV and pVmV sequences should have the following structures, where the place

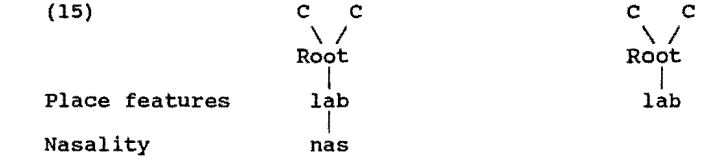
features violate the OCP.[2]

(14)



mVmV and pVpV, on the other hand, have the following structures, which do not violate the OCP.

(15)



Thus, (13) correctly predicts dissociations between /p/ and /m/, without excluding /m/-/m/ and /p/-/p/ combinations.

The dissociations between /k/ and /ŋ/ are explained in the same way: The nasality feature is dependent on the feature [dorsal], so that a combination of /k/ and /ŋ/ violates the OCP on the dorsal tier.

4.3. Underspecification

Let us now turn to the generalization (12ii). /t/ does not have any cooccurrence restriction with other coronals, while /n/ and /r/ are in dissociation with each other. We will argue that this observation is explained by the notion of underspecification discussed by Kiparsky (1982), Archangeli (1984), Ito and Mester (1986), Steriade (1987), and references cited there.

This observation suggests that /n/ and /r/ in Maori have some feature in common, while /t/ does not share that feature. [sonorant] is a good candidate. Now, consider the following list of non-continuant consonants

---

[2] I assume that /p/ is underspecified for nasality. For discussions on underspecification, see the references cited at the beginning of 4.3.

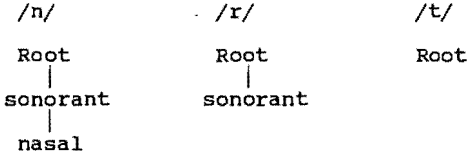
in Maori.[3]

(16) Labials: p, m
Coronals: t, n, r
Dorsals: k, ŋ

There are two consonants each for [labial] and [dorsal]: One is sonorant and the other is non-sonorant. Both sonorants are nasal, so that, if they have the nasality feature, the feature [sonorant] is redundant. On the other hand, two out of the three coronals are [sonorant], and only one of them is nasal. Therefore, the feature [sonorant] is distinctive among coronals. Thus, there is good motivation to assume that /n/ and /r/ have [sonorant] as a distinctive feature, while /t/ lacks this feature.

Suppose now Maori does not have the feature [coronal]. That is, /n/ has [sonorant] and [nasal], /r/ has [sonorant] only, and /t/ has no segmental feature in this language. Suppose further that the nasality feature for /n/ is dependent on [sonorant]. The three segments have the following feature configurations.

(17)



/n/ and /r/ cannot cooccur in a morpheme, because they would violate the OCP on the [sonorant]-tier. /t/ does not have [sonorant] and therefore is free to cooccur with other coronals.

Our hypothesis that /t/ in Maori has no segmental feature is supported by two observations. First, this hypothesis entails that /p/ and /k/ cannot be underspecified for place features, and must exhibit

---

[3] Krupa (1968:26) characterizes Maori [r] as "an alveolar consonant articulated with the tip of the tongue. It resembles the Japanese non-vibrating [r]." I assume that it is a flap, but this does not affect our argument. The only crucial assumption here is that /r/ shares [sonorant] with /n/ in this language.

dissociations with other consonants with the same place of articulation. This is borne out in Table 3.

Second, our hypothesis is supported by segmental phonology in passive and gerundive formation in Maori discussed by Hale (1973) and McCarthy (1981). Present-day Maori does not allow closed syllables, so that all verbs end in vowels in their bare forms. Where they are followed by the passive or gerundive suffix, a consonant shows up before the suffix in many cases.[4] Some examples are given in (18).

(18) active	passive	gerundive	
huri	hurihia	hurihanga	'turn'
hopu	hopukia	hopukanga	'catch'
aru	arumia	arumanga	'follow'
mau	mauria	mauranga	'carry'

What consonant appears in passives and gerundives is a lexical property of each verb.

One can account for this observation as follows. Suppose that these verb stems end in a consonant, which is deleted in the word-final position, where it is not syllabified. Suppose further that the passive and the gerundive suffixes supply not only the melody features for /ia/ and /aŋa/, respectively, but also prosodic templates that require that the suffixes begin in a consonant.[5] The stem final consonant is linked to the suffix-initial consonant slot, and is prosodically

---

[4] There are also verbs whose passive and gerundive forms do not have an additional consonant. For example,

(i) active	passive
patu	patua
kite	kitea

(Hale (1973:414))

[5] Or alternatively, a consonant is needed here to satisfy Ito's (1989) Onset Principle, which requires onsetless syllables to be avoided.

licensed in the derived words.[6]

In his discussion of Maori passives, Hale (1973) reports that t shows up in the following contexts.

(19)(i) Stems which are basically nominal are often used verbally in spontaneous discourse; when they are so used, in the passive, they regularly take the ending /-tia/.
(ii) Derived causatives (formed with the prefix /whaka-/) take /-tia/ in the passive even if the basic verb stem takes another alternant when not in the causative.
(iii) There is a rule whereby certain adverbials are made to agree in voice with the verbs they modify; these adverbials take /-tia/ in the passive regardless of the shape of the passive ending which the verb itself takes.
(iv) Borrowings from English, including unassimilated consonant final ones, take the ending /-tia/ in the passive.
(v) Compound verbs derived by incorporating a noun from an adverbial phrase regularly form their passives in /-tia/.
(vi) In general, /-tia/ can be used when the conventional passive termination for a given verb is not remembered.

(Hale (1973:417)).

A pretheoretical generalization is:

(20) Where the verb cannot provide a specific consonant, /t/ is selected. That is, /t/ shows up as a default in passives and gerundives.

This observation follows from our hypothesis that /t/ lacks segmental features in Maori. Where verbs do not provide any specific consonant, the consonant slot is simply left unspecified for segmental features, and ends up being realized as [t], because it is the phonetic value of a consonant without segmental features in this language. Though epentheses provide only weak arguments for underspecification in general, the fact here is

---

[6] This account of Maori passives and gerundives was suggested to John McCarthy by Paul Kiparsky. (J. McCarthy, personal communication.)

coherent with our hypothesis based on cooccurrences.

4.4. /w/ and /wh/

Krupa (1968:26) characterizes [w] and [wh] in Maori as follows.

(21)(i) [w]:
A bilabial oral sonorous consonant; combined with [u] and [o] [wu, wo] occurs in loan-words only, e.g. wuuru 'wool' wooro 'wall'.
(ii) [wh]:
a voiceless bilabial or a labio-dental fricative consonant, the most variable Maori consonant. The young generation pronounce it like the English [f]. The bilabial allophone is more common with the old generation as well as in several dialects. The gradual transition from the bilabial variant to the labio-dental one might be at least partially caused by the influence of English.

There are two possible interpretations of the description in (21ii). One is that /wh/ in Maori is a consonant with features [labial] and [continuant]. The other is that it is a voiceless glide. In either case, /w/ can be analyzed as its voiced counterpart.

Suppose now that /w/ and /wh/ are labial consonants, and that continuancy features are dependent on place features. (Incidentally, /w/ and /wh/ are the only segments, if any, that require continuancy as a distinctive feature in this language.) Then they should exhibit dissociation from the other labial consonants, p and m. If they are glides, they are more likely to be in cooccurrence restrictions with vowels than with consonants. Interestingly, they are in dissociation both with m/p and with back (round) vowels.

First, consider Tables 2 and 3. /w/ and /wh/ are lumped together, because they have very low frequencies. Observed frequencies are significantly lower than expected frequencies in w/wh - m, w/wh - p, and m - w/wh combinations but not in p - w/wh. Krupa (1968) counts two examples of p - w combination and one example of p - wh combination.

Following are the words with p - w/wh combinations listed in Williams's (1971) dictionary.

(22) a. pawa (i) n.
1. A form of bird snare = pewa 4.
2. A leading question, intended to draw an incriminating answer.
3. Part of a rat trap = rupe

b. pawa (ii) = paoa n. smoke

c. pewa
1. n. Anything bow-shaped; so
2. Eyebrow.
3. New moon
4. The perch of a form of bird snare; also the whole apparatus = peu.
5. In the expression pewa ika, roe of a fish. [ika ('fish') -- N.K.]
6. vi. Raise the eyebrow in wonder, anger, etc.

cf. peu n. Part of a bird snare = pewa.

d. pūwhā, pūhā n.
Sonchus oleraceus, sow-thistle; or any vegetable used as greens.

e. puwha, puha vt. spit out, belch out.

All the meanings for pawa (i) and pewa in (22ac) are clearly derived from the meaning in (22c4), for which there is an alternative pronunciation without w.[7] If this alternative pronunciation is closer to the underlying representation, these forms have only one labial underlyingly.

Krupa (1968:38) reports that most morphemes in Maori contain two vowels, and that morphemes with more vowels are rare. (He analyzes long vowels as sequences of two phonemes.) This suggests that the word in (22d)

---

[7] There seem to be two directions of meaning extension here. The original meaning is the perch of bird snares, which is probably bow-shaped in the Maori culture. One extension goes to the bird snare as a whole and then to snares and traps in general or even in a metaphoric sense as in (22a2). The other direction is to expand it to bow-shaped things like eye-brow, new moon and roe of a fish. (Fish roe is usually contained in a bow-shaped bag, when it is in mothers' body.)

consists of two morphemes. In fact, it is likely to be a compound consisting of the following words.

(23) a. pū n. bunch, bundle; anything growing in a bunch, tuft.
b. whā n. leaf

If this is the case, pūwhā is the more basic form, and the other form puha has developed in the course of its lexicalization. The development of this alternative pronunciation strongly suggests that Maori has a tendency to avoid p - wh combination.

Puwha in (22e) also has an alternative pronunciation without wh. It is also possible that this word belongs to the class of onomatopoeias, which often violate phonological constraints.

Pawa in (22b) also has an alternative pronunciation without w. It is not clear which is the more basic form, or whether it is a monomorphemic or bimorphemic word, though it is possible that the first half of the word is related to the verb pa (vi. 'to blow').

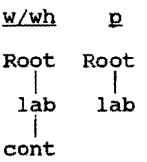
In short, it is very likely that the forms in (22) are not true examples of p - w/wh combinations and we can conclude that w/wh are in dissociation with m and p in any order.

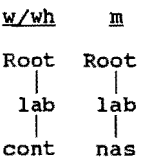
On the other hand, Krupa (1968:42) reports that there are no bi-vocalic morphemes containing /w/ or /wh/ immediately followed by /o/ or /u/ (except for loan words) in Maori. /u/ and /o/ are back and round vowels in this language. No such strong dissociations are reported for /m/ and /p/.

In sum, w/wh are in dissociation both with labial consonants m/p and with rounded vowels u/o, while m/p are not in dissociations with rounded vowels. One possibility to account for these dissociations is to assign w/wh a status of being partially consonantal and partially vocalic, so that they can interact with either class.

As was suggested above, the dissociation from labial consonants can be accounted for in the same way as other dissociations we have seen so far. If continuancy is dependent on the labial node, the representations for combinations of w/wh and m/p violate the

OCP on the labial tier as shown in (24).

(24) a. 

b. 

The dissociations between w/wh and back round vowels seem to be of a different kind. First, the dissociations seem to be uni-directional and limited within syllables. I found two bimoraic words (kuwha and rowi) in Williams (1971) which contain w/wh immediately preceded by a back vowel. It is difficult to evaluate the significance of this number, for the frequencies of /w/ and /wh/ are low in general in this language. However, there are many words with three moras or more where a back vowel immediately precedes w/wh. There are also many bimoraic words that begin in w/wh and end in a back vowel. Thus, there is at least no strong dissociation in u/o - w/wh combinations in this order or in w/wh - u/o combinations across syllable boundaries which is comparable to the dissociations of w/wh - u/o combinations within syllables. Second, many languages that do not have dissociations among consonants as those observed in Maori still disallow combinations of w/wh and a back (round) vowel where they appear as the onset and the nucleus of the same syllable. These observations suggest that the dissociations between w/wh and back vowels in Maori are related to syllabification, and are different in nature from the dissociations among consonants. I will not pursue this topic any further in the present paper.

There is another interesting observation on /wh/. It exhibits dissociation from /h/ in the wh - h combination, while /w/ shows no dissociation from /h/ in any order, as shown in (25).

(25)	wh-h	h-wh	w-h	h-w
observed frequency:	0	1	7	5
expected frequency:	6.52	2.90	5.84	3.86
X^2:	6.52	--	0.23	--

The expected frequency of the h - wh combination is not high enough to draw any conclusion from the X^2-value.

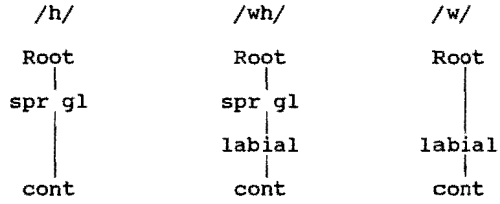
However, Krupa (1968) counts only one example of this class, which is very likely to be one of the following, cited here from Williams (1971).

(26) a. hawhe = whawhe
1. vi. Go or come round.
2. n. The end section of a dragnet or kaharoa.
3. Turn or bend in a fence.

b. hūwhā, hūhā n. thigh

Notice that both forms have an alternative pronunciation with two identical consonants. If these alternative pronunciations reflect their underlying representations more directly, they are not counterexamples to the dissociation between /wh/ and /h/.[8] /wh/ and /h/ are the only segments in Maori that are characterized as having the distinctive feature [spread glottis] proposed by Halle and Stevens (1971). Thus, one might extend the above analysis of consonants and assume that the place feature [labial] is dependent on this feature as illustrated in (27).

(27)



A sequence of /h/ and /wh/ in a single morpheme violates the OCP on the [spread glottis] tier.

This analysis accounts for the observation that there are dissociations between /h/ and /wh/ as well as between /wh/ or /w/ and other labial consonants (/m/ and /p/). It also predicts that there should be no dissociations between /w/ and /wh/. It is difficult to see whether this is a desirable result. Though Krupa (1968) reports that there are no bimoraic words of w - wh or wh - w combinations, its significance is difficult

[8] It is not clear whether hūwhā/hūhā is monomorphemic or bimorphemic.

to evaluate because the expected frequencies of these combinations are very low in this language. At least, the analysis is not falsified by Krupa's data. However, the very nature of the dissociations among consonants in Maori is that similar but not identical phonemes cannot cooccur in a morpheme, and /w/ and /wh/ meet the characterization as "similar but not identical." Therefore, it is a potential problem to our analysis that it predicts no dissociations between /w/ and /wh/. But we will not go into this problem any further in the present paper.

4.5. Nasals

4.5.1. Assimilation

We have seen all the dissociations among Maori consonants except one. We will now discuss the last case: the significantly low frequency of n -ŋ combination. /n/ and /ŋ/ share the nasality feature, but differ in other features. We proposed that /ŋ/ has the place feature [dorsal] in 4.2, and that /n/ has the feature [sonorant] in 4.3.

Three observations indicate that the dissociation between /n/ and /ŋ/ is of a different kind from those we have seen so far.

First, this is the only significant dissociation observed among nasals. There is no significant dissociation between /m/ and /n/ or between /m/ and /ŋ/.

Second, the dissociation is uni-directional. No significant dissociation is observed in the ŋ - n combination in this order. Krupa (1972) reports that there are four examples of ŋ - n. This is lower than the expected frequency 9.23, but the X^2-value is 2.97, so that the difference is not significant at the 0.05 level. Williams (1971) gives four words of the form ŋVnV: ngana, ngene, ngeni, and ngunu. Ngene has an alternative pronunciation nene for one of its meanings. The other three, however, do not have alternative pronunciations of the form nVnV or ŋVŋV. Therefore, there is no fact suggesting that they have identical consonants underlyingly as in the case of h - wh discussed in 4.4. above. Maori allows the ŋVnV sequence underlyingly.

Third, the dissociation of n - ŋ combination in this order is complete. The observed frequency is zero,

while in many of other cases, observed frequency is not zero, though significantly lower than the expected frequency.

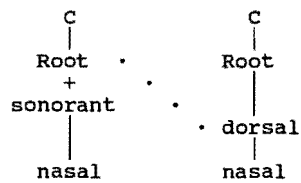
In addition, a significant association is observed in the ŋ - ŋ combination. In fact, the dissociation of n - ŋ and the association of ŋ - ŋ completely disappear, if we lump these combinations as shown in (29).

(28) Observed frequency of n - ŋ and ŋ - ŋ: 11
Expected frequency of n - ŋ and ŋ - ŋ: 11.06
(with N_i = 82, N_j = 81 + 88 = 169)
X^2 for n - ŋ and ŋ - ŋ lumped together: 0.0000229

The observed frequency of n - ŋ and ŋ - ŋ lumped together is very close to the expected frequency of these combinations.

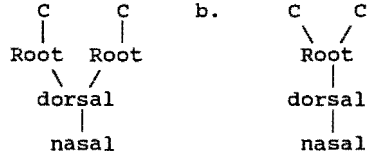
These four observations all follow, if Maori has the following rule of place assimilation, which changes n - ŋ combination into ŋ - ŋ.

(29)



This rule creates the structure (30a), where two root nodes share all the segmental features. One can assume that the structure is then reanalyzed as (30b).

(30) a. b.



One might want to generalize the rule (29), so that the place node rather than the dorsal node spreads to the preceding nasal segment that lacks a place feature. This would make the assimilation rule applicable to n - m, as well as to n - ŋ, and predict that there should be no morpheme with the surface n - m combination in the

language. Krupa (1968) counts two bimoraic words with this combination, which are very likely to be namu ('Austrosimulium, sandfly') and numi ('to bend, fold'). These words do not have alternative pronunciations. The expected frequency of this combination (in this order) is 4.51. Though the observed frequency is lower than the expected frequency, the latter is already very low, and we cannot determine whether there is a significant dissociation. At least, there is no complete dissociation that the alternative formulation would predict. Thus, we assume that the assimilation rule must mention the feature [dorsal]. A different formulation of the rule will be discussed in Section 7.

We have proposed a rule that assimilates /n/ to the following /ŋ/, based on the dissociation of n -ŋ and the association of ŋ - ŋ. In the following subsection, We will see this hypothesis is supported by the phonology of Maori gerundives.

4.5.2. Haplology in Maori gerundives

Compare the following examples with (18).

(31)	active	passive	gerundive	
a.	paa	paangia	paanga	'touch'
	tohu	tohungia	tohunga	'point out, mark'
b.	hua	huaina	huanga	'name, think'
	ua	uaina	uanga	'rain (vt.)'

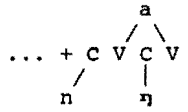
The verbs in (31a) require /ŋ/, and those in (31b) require /n/ in the passive. The nasal is metathesized with the vowel /i/ in the latter case. Their gerundive forms, however, end in /ŋa/ rather than in expected /ŋaŋa/ or /naŋa/. This is an example of haplology, a phenomenon where an expected string does not show up in the environment of an identical or close to identical string. However, as McCarthy (1981:240) points out, the phonological rule that describes this phenomenon in Maori gerundives will be a complex one with disjunction in its structural description.

(32) $\begin{bmatrix} \text{nasal} \\ \text{coronal} \\ (\quad) \\ \text{dorsal} \end{bmatrix}$ + a ŋ a

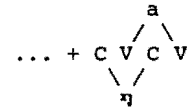
1 2 3 4 → φ φ 3 4

Suppose now that ...n+aŋa sequences undergo the assimilation rule (29) first, to give ...ŋaŋa sequences as follows.

(33) a.

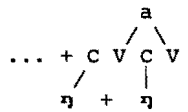


b.

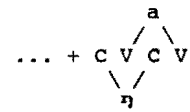


Also suppose that ...ŋ+aŋa sequences undergo the following restructuring, for the original structure (34a) violates the OCP on the segmental tier for consonants. We assume that the morpheme boundary between the two nasals does not block the OCP, because they are linked to the consonant slots on the same tier.

(34) a.



b.

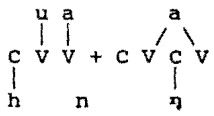


The underlying ...n+aŋa and ...ŋ+aŋa now have the structures where two consonant slots are linked to the segmental features of /ŋ/. The deletion rule does not need disjunction any more. One can formalize it as follows.

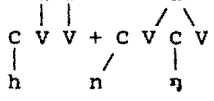
(35)

For example, the derivation of huaŋa in (31b) is given in (36).

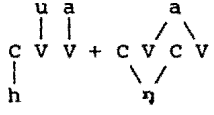
(36) a. Underlying Representation:



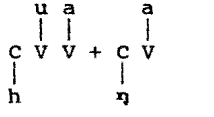
b. Association of the melody to the prosodic template:



c. Assimilation (29):



d. Haplology (35):

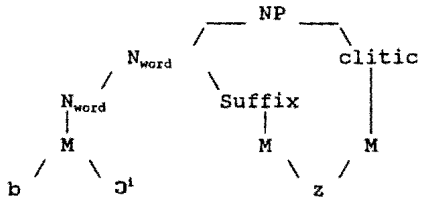


To sum up, disjunction can be eliminated from the rule of haplology in Maori gerundives, if we assume that it applies after the assimilation rule (29) has applied. The assimilation rule was proposed on the basis of the dissociations and associations among consonants, and it finds an independent motivation in the segmental phonology of the language.

Notice that the rule (35) for haplology is very much like degemination rules, the only difference being that it involves two pairs of identical segments, each of which is reduced to a single segment, and that the identical segments, in each case, are not adjacent to each other.

Stemberger (1981) discusses haplologies in other languages. He calls these cases morphological haplologies, because they require an affix or clitic to be absent in the environment of homophonous strings. He proposes to assign morphemes a status as a prosodic unit, and to allow ambimorphemic structure as in (37), which represents the structure of boys' as in boys' shirts.

(37)



M stands for morpheme.

The segment /z/, which is added as a pluralizing suffix, is reinterpreted as a possessive marker, and therefore belongs to two morphemes. Stemberger claims that boys' is not derived by first adding two /z/'s to the noun and then deleting the second /z/; there is only one /z/ on the segmental tier throughout the derivation.

Stemberger's analysis based on ambimorphemicity cannot be extended to the Maori case discussed above. First, it is not the whole suffix -aŋa but a syllable ŋa that is missing in Maori gerundives. In fact, it is not clear whether this syllable is a substring of the suffix or the stem-final n plus the suffix-initial a, or whether one can, or should, choose between these two possibilities. In any case, the final vowel of the gerundive form ...ŋa comes from the suffix. This means that at least the segmental features for /a/ must be added to the segmental tier of the stem. There is no way to construct an ambimorphemic structure by reinterpreting the end substring of the stem.

Second, we have seen that disjunction can be eliminated from the conditions for this haplology, if we assume that it applies after the assimilation rule (29) has changed ...n+aŋa to ...ŋaŋa. The assimilation, in turn, is possible only if the segmental features of the suffix have been added to the segmental tier(s) of the stem, a step that Stemberger's analysis denies.

Thus, the Maori gerundives ending in ...ŋa are derived by (non-vacuous) suffixation, assimilation of /n/ to /ŋ/, and deletion of a CV sequence on the CV-tier.

One might claim that universal grammar permits two types of systematic haplology: cases of ambimorphemicity and cases like Maori gerundives, which are explained by complete suffixation followed by (local or long-distance)

degemination. Though it is not implausible, the Maori case certainly weakens Stemberger's claim that ambimorphemicity is necessary in grammar, for the phonological account proposed here for Maori seems to be also applicable to at least some of the cases he discusses.[9]

4.6. Summary

Let us summarize the discussions of the cooccurrence restrictions in Maori. Many of the significant dissociations observed in Maori follow from the OCP and the following configurations of feature specifications: [nasal] and [continuant] are dependent on place features for labials and dorsals, [nasal] is dependent on [sonorant] in the case of /n/, which we claimed to have no place feature, and /wh/ has the feature [labial] dependent on [spread glottis].

The lack of dissociations involving /t/ suggests that /t/ is underspecified for place features in Maori, which is supported by the segmental phonology of passive and gerundive suffixes in this language.

Contrary to Krupa's (1966, 1971) claim, velar consonants exhibit dissociations. /h/ has no cooccurrence restrictions with other back consonants, which indicates that it should be excluded from this class.

The dissociations between w/wh and back (round) vowels are of a different kind, and seem to be related to syllabification.

The dissociation of n - ŋ combination is also different from other dissociations among consonants, in that it is complete and uni-directional. It is also the only dissociation among nasals. We proposed an assimilation rule to explain this dissociation, which receives an independent motivation from the haplology in

---

[9] Stemberger (1981:797) reports that the possessive suffix -s and the collective suffix -s in Swedish show haplology after all sibilants, and that it is always the suffix -s that is missing in such cases. It is possible that /s/ is less fully specified in feature specification than other sibilants, and that this (apparent) priority of the stem segments follows from the feature system of the sibilants in this language.

Maori gerundives. This haplology cannot be explained by Stemberger's (1981) account based on ambimorphemicity, but should be explained by complete suffixation and deletion. The deletion rule deletes a CV-sequence on the CV-tier, and reduces long-distance geminates to singletons. The assimilation rule applies after the suffixation and before the deletion.

5. Back Consonants

Let us go back to the question we raised in (10ii). Among the languages discussed in Krupa (1966, 1971), only Fijian and Proto-Austronesian are reported to show dissociations among back consonants. A more detailed examination of Maori in the preceding section, however, showed that back consonants (dorsals) have the same type of dissociations as front (labial) and middle (coronal) consonants. Unfortunately, no such detailed data on other languages have been available to me. However, Krupa (1966) provides inventories of the consonants in the languages discussed in that article. They are summarized in (38). Underlines indicate the classes where significant dissociations are reported in Krupa (1966).

(38)

	Front	Middle	Back
Hawaiian	m, p, w	n, l	k, ?, h
Tuamotuan	m, p, v, f	n, r, t	ŋ, k, h
Maori	m, p, w, f	n, r, t	ŋ, k, h
Fijian	m, b, v, w	c, d, dr, l, n, r, s, t, y	ŋ, k, g
PPN	m, p, w, f	l, n, r, s, t	ŋ, k, h, ?
PAN	m, b, p, v	n, d, t, l, d, t, l, n^y, d^y, t^y, q^y, k^y, j	ŋ, g, k, r, h

PPN: Proto-Polynesian
PAN: Proto-Austronesian

Those languages for which no significant B-B dissociations are found by Krupa (1966) have either /h/ or /h/ and /?/ in this class. This suggests that dissociations among dorsals have been disguised by the inclusion of these segments in this class, just as dissociations between /k/ and /ŋ/ were disguised by the inclusion of /h/ in Maori. This is supported by the observation that Fijian, in which B-B dissociations are found significant, has velar and uvular consonants but not /h/ or /?/.

Though we still need to look into the nature of /h/ and /?/ and cooccurrence restrictions on other back consonants in these languages, it seems plausible that /h/ and /?/ should be analyzed as having no place feature and therefore have no cooccurrence restrictions, while other back consonants, having [dorsal], are subject to the same kind of dissociations as labials and coronals.

6. Hawaiian Middle Consonants

We now turn to the question (10iii). Krupa (1966, 1971) reports that dissociations among middle consonants (coronals) are found in all the languages he discusses except for Easter Island and Hawaiian. To see why these two languages do not have dissociations among middles, consider the inventories of consonants in (38) again.

Hawaiian has no three-way place-distinctions; there are only two stops (/p/ and /k/) and two nasals (/m/ and /n/). Suppose that Hawaiian has only one place feature [labial] underlyingly, other places being specified later (possibly by phonetic implementation). Then it follows that /n/ and /l/ (and also /k/) do not have place features in the underlying representations. Suppose /n/ has only one segmental feature [nasal] and /l/ has only one feature [lateral]. Then, there are no dependency relationships among features, and therefore there should be no dissociations among these segments.

We have proposed in 4.3. that Maori does not have the feature [coronal] and that /t/ in Maori has no segmental features. We have seen that this analysis is supported by the phonology of passives and gerundives, where /t/ serves as a default consonant. Our proposal here is that Hawaiian has dropped another place feature: [dorsal]. Among the segments that lack place features, /n/ and /l/ have [nasal] and [lateral], respectively, and /?/ and /h/ have laryngeal features. This allows /k/ to lack any segmental features, as in the case of /t/ in Maori. In fact, /k/ in Hawaiian seems to have (or at least have had) the same function as a default as /t/ in Maori. Hale (1968:417) reports that the Hawaiian passive suffix corresponding to that in Maori always has the form /-?ia/, and notes that this presumably derived from */-kia/. This suggests that Hawaiian has undergone the following historical changes.

(39)(i) Hawaiian has lost place features [coronal] and

[dorsal].
(ii) All the verbs lost lexical information as to what consonant should appear in their passive forms, and /?/ is added to the underlying representation of the passive suffix to give /-?ia/.

Suppose that (i) and (ii) took place in this order. Then, during the period when Hawaiian had undergone (i) but not (ii), /-kia/ should appear as the default form for passives.

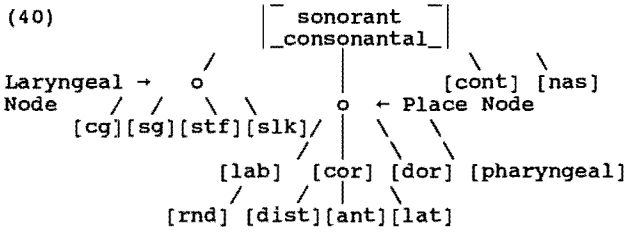
7. Residual Problems

We have proposed an account of cooccurrence restrictions among consonants in Polynesian languages along the lines of Mester (1986). Our discussions, along with Mester's analysis of Javanese, raises three questions, which are related to each other.

First, the analysis proposed here and Mester's analysis of Javanese motivate phonological representations in which some segmental features are dependent on others. The arguments for such representations are based on dissociations among consonants, which are analyzed as OCP effects. This is reminiscent of studies of feature geometry, a theory of phonological representations which argues for dependency relationships among segmental features. However, the two approaches differ crucially as to what features may enter dependency relations with each other, and therefore they motivate significantly different representations.

The arguments for feature geometry are based on purely phonological considerations, such as investigations of phonological regularities that can be explained by spreading, delinking, the OCP, and so on. However, the representations proposed in feature geometry correspond to the structure of speech-producing apparatus (or the mental picture of speech-producing apparatus), as explicitly argued by Mohanan (1983) and Clements (1985). Features corresponding to different dimensions of speech production form separate blocks in feature geometry. For example, McCarthy (1988) proposes the following schema for the representation of segmental features, based on phonological regularities in various languages. The major class features ([sonorant] and [consonantal]) form the Root node here.

(40)



[cg]	constricted glottis	[cont]	continuant
[sg]	spread glottis	[nas]	nasal
[stf]	stiff glottis	[rnd]	round
[slk]	slack glottis	[dist]	distributed
[lab]	labial	[ant]	anterior
[cor]	coronal	[lat]	lateral
[dor]	dorsal		

[distributed], [anterior], [lateral] are dependent on [coronal], and this corresponds to the fact that they all specify the place of articulation, and that the first three provide more detailed place distinctions among coronals. [continuant] is independent of place features, and this corresponds to the fact that they specify different dimensions of speech production; closure may be complete or incomplete no matter where it is formed in the speech organ. [nasal] is independent of all these, corresponding to the fact that it is possible to release or block the air stream through the nasal cavity, regardless of the place and the manner of oral constriction. These features are independent of laryngeal features, which specify another dimension in speech production.

On the other hand, our analysis of Maori motivates phonological representations where [nasal] and [continuant] are dependent on place features, and the place feature [labial] is dependent on the laryngeal feature [spread glottis]. Mester (1986) argues that the nasality feature and the voicing feature are dependent on place features in Javanese. The features that enter dependency relations in these analyses specify different dimensions of speech production, and therefore conflict with the view that phonological representations of segmental features correspond to the structure of speech production. How can we settle this conflicting situation? Should we reject one type of representation

totally in favor of the other, or do languages like Maori and Javanese have one type of representation at one level and the other at another level?

A closely related question arises as to cross-linguistic variations. There are many languages which do not have cooccurrence restrictions as observed in Maori and Javanese. It is not enough to say, for example, that Maori and Javanese have Mesterian representations (henceforth, M-type representations), while languages without such cooccurrence restrictions have representations proposed in feature geometry (henceforth, FG-type representations). The real question is why these languages have different types of representations (if this is indeed the case).

The third question is concerned with the exceptions to dissociations. How is it possible that the dissociations are incomplete? Does it mean that lexical items may be specified as exceptions to the OCP? Or do exceptional morphemes differ from others in feature configurations, so that they do not violate the OCP?

I would like to conclude this paper with a couple of speculations about these questions.

Studies on Lexical Phonology (e.g., Kiparsky (1982, 1985) and references cited there) have shown that cyclic rules of phonology are prevented from applying in non-derived environments. Consider now the rule (35) for haplology. Maori has a morpheme nganga, which suggests that this rule is a cyclic rule and does not apply in underived environments. However, we argued in 4.5.2. that the assimilation rule (29) applies before the haplology. In order to explain the dissociation of n - ŋ combination, the assimilation rule must be allowed to apply within morphemes.[10] Does this mean that the

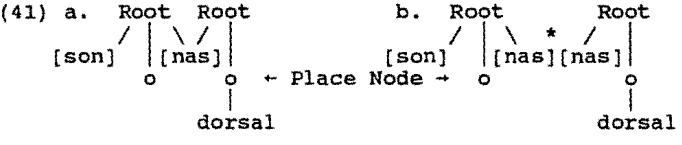
---

[10] There seem to be no data accessible to children learning Maori as their first language that tell them which morphemes of the form ŋVŋV have underlying nVŋV sequence and undergo the assimilation. If this is the case, all these morphemes must be listed in the lexicon as ŋVŋV with /ŋ/ linked to two consonantal positions. The assimilation rule has no effect on these underived words, but it prevents new morphemes of the form nVŋV from entering the language through borrowing, thus keeping the observed frequency of such morphemes

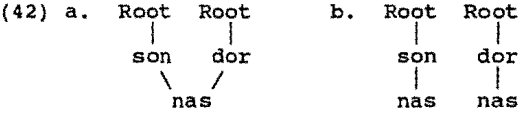
assimilation rule is a cyclic rule but is allowed to apply in underived environments?

When I formulated the assimilation rule in 4.5.1., I assumed that this rule applies to the M-type representation, and that /n/ and /ŋ/ sequences do not share the specification for nasality, without discussing other possibilities. Let us now consider a different formulation.

Consider first what configurations the two types of representations require for n - ŋ sequences. In FG-type representations, /n/ and /ŋ/ must share the nasality feature as in (41a), for the representation (41b) violates the OCP on the nasality tier.



The status of the nasality feature is less clear in M-type representations. One might claim that (42b) is not a well-formed structure, because it violates the OCP on the nasality tier.



Notice, however, that the specifications for nasality in (42) are dependent on different features on different tiers. It is possible that identical features are on different tiers, if they are dependent on different

---

zero. This does not affect our argument that the assimilation is allowed to apply in mono-morphemic words, for we would lose an explanation of the total dissociation of n - ŋ otherwise. The rule itself is learnable from the data on gerundive forms.

tiers,[11] or that the OCP prohibits identical features only if they are linked to adjacent positions on the same tier. In the former case, (42b) is the only possible representation for nVŋV sequences. The latter case allows both (42ab). If nodes are not allowed to be linked to different tiers simultaneously, again (42b) is the only possibility for nVŋV.[12] Suppose that this is the correct result, and suppose further:

(43)(i) Maori morphemes have M-type representations underlyingly.
(ii) The M-type representations are then restructured into FG-type representations.

Morphemes of the form nVŋV have (42b) as underlying representation, and are restructured into (41a).

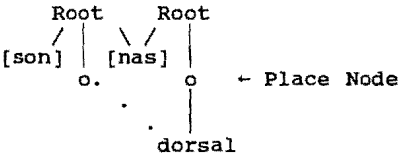
It seems that it is not accidental that the two segments related by the assimilation rule are both nasal. To capture this, the rule must specify a doubly-linked [nasal] in its structural description. Assuming the above discussions, the assimilation rule can apply only to the FG-type representation (41a). That is, its structural description is satisfied only after the restructuring (43ii). In other words, the restructuring creates environments to which the assimilation rule can apply. If this analysis is on the right track, the assimilation rule applies only to derived environments. We reformulate this rule as follows.

---

[11] Selkirk (1988) proposes on independent grounds that identical features define a tier if and only if they are dependent on identical features.

[12] If this is correct, [labial] in the feature configurations for /wh/ and /w/ in (27) and [labial] in the feature configuration for /p/ and /m/ (See (14)) should not violate the OCP, where they are adjacent to each other, and it wrongly predicts that w/wh can cooccur with p/m. Lisa Selkirk pointed out to me an alternative analysis where [spread glottis] is dependent on [continuant], and has an additional property that it cannot be doubly-linked.

(44)



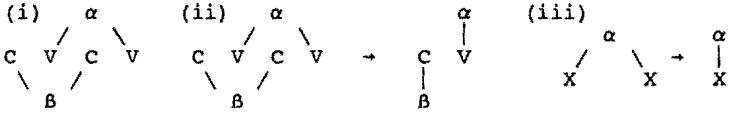
The haplology rule, on the other hand, requires that there be a single root node which is linked to two consonantal slots and which contains [nasal] and [dorsal]. It is immaterial to the rule how these two features are positioned with respect to each other. Morphemes of the form ŋVnV satisfy the requirement both before and after the restructuring. Therefore, the restructuring does not create a derived environment for the haplology, and the rule does not apply to nganga.[13]

We have pointed out the possibility that Maori morphemes have M-type representations underlyingly, and are restructured into FG-type representations. This suggests a possible solution to the third problem raised above: Why do the dissociations have exceptions? Suppose some morphemes exceptionally have FG-type representations underlyingly. Then, they should exhibit no dissociations of the type discussed in the present

---

[13] Maori allows nga-ngana as a reduplication of ngana. It contains a derived environment that satisfies the structural description of the haplology. The haplology must be blocked from applying to such cases, which requires a different explanation.

Reduplication and gerundive formation seem to be the only processes in Maori that produce derived structure of the form (i). Thus, assuming that the haplology is correctly blocked in reduplicated forms by some mechanism, one can eliminate all the melodic information from the haplology rule (35) and generalize it as in (ii).



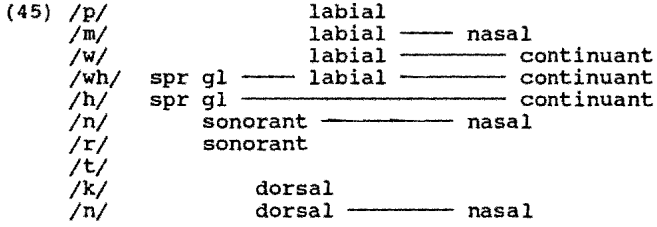
In fact, (ii) can be further simplified as in (iii), i.e., to a simple degemination rule.

paper. If the language allows such exceptional morphemes, the dissociations will not be complete.

Finally, let us consider briefly the problem of cross-linguistic variations. Our discussions above suggest that all languages have FG-type representations at least at later stages of phonological derivation (and possibly they form the basis of phonetic realization). Languages like Maori have M-type representations underlyingly, while others have FG-type representations throughout the derivation. If this is correct, the question of language variations can be restated as follows: Why do some languages have M-type representations in addition to FG-type representations, while others do not?

I do not have an answer to this question. But I would like to point out that Maori consonant system has a remarkable property, which might be related to this question. (45) summarizes the features we proposed for Maori consonants. The horizontal lines indicate dependency relationships in M-type representations.

(45)



Maori has a very small number of consonants, and a very small number of features to distinguish among them. All the features we proposed are privative. As a result, each phoneme has a very small number of feature specifications. When put into FG-type representations, Maori consonants exhibit very few dependency relations among features. Given the schema (40) for FG-type representations, for instance, only /n/ has a dependency relation among features (which is unavoidable, because the feature [sonorant] forms the root node in this schema).

Note also that the differences between the M-type representation and the FG-type representation are not arbitrary. Assuming again the schema (40) for FG-type

representations, one can determine M-type representations in most cases by making [continuant] and [nasal] dependent on place features. (The only remaining case is the status of [spread glottis] for /wh/, for which I pointed out a potential problem in 4.4.) These observations suggest a tendency to increase dependency relations at underlying representation. Obviously, the number of dependency relations that feature geometry gives is not the only factor that motivates the M-type representation, for there are languages with a small number of consonants (and a small number of dependency relations in the FG-type representation) that do not exhibit dissociations of the kind observed in Maori. The relevance of the above observations to the problem of language variations, however, remains to be examined.

These remarks are, needless to say, very speculative, and await examination by further research.

Acknowledgment:

I would like to thank John J. McCarthy for his comments and advice. I am also thankful to Roger Higgins, Lisa Selkirk, François Dell, Yasuo Ishii, and Juliette Levin for their comments.

References:

Archangeli, D. 1984 Underspecification in Yawelmani Phonology and Morphology, Doctoral dissertation, MIT.

Clements, G. N. 1985 "The Geometry of Phonological Features," Phonology Yearbook 2, 225-252.

Hale, K. 1973 "Deep-Surface Canonical Disparities in Relation to Analysis and Change: An Australian Example," in T. Sebeok, ed., Current Trends in Linguistics 11, Mouton, 401-458.

Halle, M. & K. Stevens 1971 "A Note on Laryngeal Features," Research Laboratory of Electronics Quarterly Progress Report 101, 198-213.

Ito, J. 1989 "A Prosodic Theory of Epenthesis," to appear in Natural Language and Linguistic Theory 7.

Ito, J. & R. A. Mester 1986 "The Phonology of Voicing in Japanese: Theoretical Consequences for Morphological Accessibility," Linguistic Inquiry 17:1, 49-73.

Kiparsky, P. 1982 "Lexical Morphology and Phonology," in I.-S. Yang, ed., Linguistics in the Morning Calm, Hanshin, 3-91.

Kiparsky, P. 1985 "Some Consequences of Lexical Phonology," Phonology Yearbook 2, 85-138.

Krupa, V. 1966 "The Phonemic Structure of Bi-Vocalic Morphemic Forms in Oceanic Languages," Journal of the Polynesian Society 75, 458-497.

Krupa, V. 1968 The Maori Language, Nauka Publishing House.

Krupa, V. 1971 "The Phonotactic Structure of the Morph in Polynesian Languages," Language 47, 668-684.

Leben, W. 1973 Suprasegmental Phonology, Doctoral dissertation, MIT.

McCarthy, J. J. 1981 "The Role of the Evaluation Metric in the Acquisition of Phonology," in C. L. Baker & J. J. McCarthy, eds. 1981 The Logical Problem of Language Acquisition, The MIT Press, 218-248.

McCarthy, J. J. 1986 "OCP Effects: Gemination and Antigemination," Linguistic Inquiry 17:2:207-263.

McCarthy, J. J. 1988 "Feature Geometry and Dependency," ms., University of Massachusetts, Amherst.

Mester, R. A. 1986 Studies in Tier Structure, Doctoral dissertation, University of Massachusetts, Amherst.

Mohanan, K. P. 1983 "The Structure of the Melody," ms., MIT.

Sagey, E. C. 1986 The Representation of Features and Relations in Non-Linear Phonology, Doctoral dissertation, MIT.

Selkirk, E. O. 1988 "Dependency, Place, and the Notion 'Tier'," paper presented at 1988 Annual Meeting of the Linguistic Society of America.

Stemberger, J. P. "Morphological Haplology," Language 57, 791-817.

Steriade, D. 1987 "Redundant Values," CLS 23:2, 339-62.

Williams, H. W. 1971 A Dictionary of the Maori Language, A. R. Shearer, Government Printer.

Appendix:

Table 1: Consonantal Combinations in the Bi-Vocalic Forms in Maori (Krupa (1968:45))

\C2 C1	0	m	p	w	wh	n	r	t	k	ŋ	h	Nj
0	19	10	13	7	6	15	20	19	21	8	20	158
m	15	7	2	0	0	15	21	15	19	10	15	119
p	22	0	7	2	1	14	19	17	16	5	16	119
w	9	0	0	2	0	7	11	7	7	1	7	51
wh	14	0	0	0	3	6	9	11	7	7	0	57
n	16	2	8	4	2	12	2	6	16	0	13	81
r	22	10	13	4	5	6	19	15	20	10	16	140
t	22	13	13	4	6	16	21	11	21	14	14	155
k	22	15	15	6	2	18	20	18	15	3	21	155
ŋ	20	1	1	2	1	4	19	11	5	11	13	88
h	21	12	6	5	1	19	20	8	21	13	9	135
Ni	202	70	78	36	27	132	181	138	168	82	144	1258

Table 2: Expected Frequencies $E_{ij} = N_i \times N_j / N$

C1 \ C2	o	m	p	w,wh	n	r	t	k	ŋ	h
o	25.37	8.79	9.80	7.91	16.58	22.73	17.33	21.10	10.30	18.09
m	19.10	6.62	7.38	5.96	12.49	17.12	13.05	15.89	7.76	13.62
p	19.10	6.62	7.38	5.96	12.49	17.12	13.05	15.89	7.76	13.62
w,wh	17.34	6.01	6.70	5.41	11.33	15.53	11.84	14.42	7.04	12.36
n	13.01	4.51	5.02	4.06	8.50	11.65	8.89	10.81	5.28	9.27
r	22.48	7.79	8.68	7.01	14.69	20.14	15.36	18.70	9.13	16.03
t	24.89	8.62	9.61	7.76	16.26	22.30	17.00	20.70	10.10	17.74
k	24.89	8.62	9.61	7.76	16.26	22.30	17.00	20.70	10.10	17.74
ŋ	14.13	4.90	5.46	4.41	9.23	12.66	9.65	11.75	5.74	10.07
h	21.68	7.51	8.37	6.76	14.17	19.42	14.81	18.03	8.80	15.45

Table 3: Chi-square values $X^2 = (O_{ij} - E_{ij})^2 / E_{ij}$

C1\C2	0	m	p	w,wh	n	r	t	k	ŋ	h
0	1.60	0.17	1.05	3.27	0.15	0.32	0.16	0.00	0.51	0.20
m	0.88	0.02	**D3.92**	**D5.96**	0.50	0.88	0.29	0.61	0.65	0.14
p	0.44	**D6.62**	0.02	1.47	0.18	0.21	1.19	0.00	0.98	0.42
w,wh	1.85	**D6.01**	**D6.70**	0.41	0.25	1.28	3.19	0.01	0.13	2.33
n	0.69	-	1.77	-	1.44	**D8.00**	0.94	2.48	**D5.28**	1.50
r	0.01	0.63	2.15	0.56	**D5.14**	0.06	0.01	0.09	0.08	0.00
t	0.34	2.22	1.20	0.65	0.00	0.08	2.12	0.00	1.50	0.79
k	0.34	**A4.71**	1.51	0.01	0.19	0.24	0.06	1.57	**D4.99**	0.60
ŋ	2.44	-	3.63	-	2.97	3.17	0.19	**D3.87**	**A4.83**	0.85
h	0.02	2/68	0.67	0.09	1.65	0.02	3.13	0.49	2.00	2.69

A: Significant association with X^2-value greater than 3.84
D: Significant dissociation with X^2-value greater than 3.84
-: The expected frequency is lower than 5.00.
Underlines: Combinations of /t/ and other coronals.