Te Reo 40 (1997)10–44

A Co-occurrence Restriction in Maori*

Paul de Lacy
University of Auckland

1. Introduction

The Polynesian language Maori has a number of well-known co-occurrence restrictions on labial segments, listed in (1):

(1) *wu *wo *whu *who

At first glance these seem to be transparently related. Accordingly, it is reasonable to expect that discerning a common underlying motivation for these prohibitions would be a straightforward, even trivial, matter. It is somewhat surprising, then, that this assumption is not entirely valid. In fact, this seemingly simple phonological problem will be shown to be the result of a complex interaction of non-obvious constraints. In the process it will be demonstrated that the most parsimonious explanation is provided by a parallelist conception of phonological computation, specifically Optimality Theory. In addition, the grammar's tendency to representational and computational parsimony will be shown to play an essential part in providing a solution, validating the notion of featural underspecification (Kiparsky 1982, Archangeli 1984, cf Steriade 1995).

Of course, before the co-occurrence restrictions can be discussed in depth, it is necessary to consider a few basic facts of Maori phonology.

The Maori language has a set of phonemes that is similar to many other Polynesian languages. While the vowels are only five in number (/i e a o u/) the consonant inventory is considerably richer with three voiceless stops (/p t k/), their corresponding nasals (/m n ŋ/), one rhotic (/r/[1]), the labio-velar glide (/w/), the glottal fricative /h/, and the labial fricative 'wh'. Of these 'wh' exhibits the most variation between dialects. Since this consonant plays a crucial role in the phenomena under discussion a fuller treatment of it will be given below.

---

* Thanks to Wayne Lawrence for providing many significant comments and the original impetus for this paper. Thanks are also due to Harry Leder, George Puttner, and two anonymous reviewers. All Maori words and their glosses are from Williams (1971).

[1] This sound is phonetically realised as a voiced tap (Bauer 1993:533). It will be represented as phonemic /r/ in this analysis.

2. The Problem

Superficially, it seems that the sequences in (1) are prohibited by a phonological constraint on adjacent labial sounds.[2] However, this is obviously too general a statement as the labial consonants /p/ and /m/ can freely combine with the labial vowels /o/ and /u/:

(2) pou 'consumed' puku 'secretly'
mouki '*Asplenium bulbiferum*' mure 'slander'

Evidently, the class of affected sounds must be further refined. This is achieved by noting that 'wh' and /w/ are distinguished from /p/ and /m/ by the feature [+continuant]. Since all vowels are also continuants (Halle & Clements 1983:7), it seems reasonable to assume that the restriction is better stated as a prohibition on *adjacent labial continuants.*

However, there is even further need of refinement here since this prohibition would prevent /ou/ sequences, for both /o/ and /u/ are labial sounds. That this is undesirable is shown by *pou* and *mouki* in (2). So, more specifically, there is a constraint on adjacent labial continuants *in the configuration 'CV'.*

At this point, the restriction seems easy to characterise. However, Bauer (1993:570) notes one other significant fact. There are a number of forms where /w/ has been deleted *following* a labial vowel (i.e. in the configuration VC):

(3) kowera > koera 'broken (clouds)'
tauwehe > tauehe 'separate'

Despite Bauer's uncertainty as to whether the deletion is a diachronic change, a dialectical variation, or a synchronic process, the fact remains that there is still evidence of a systematic prohibition (or at least avoidance) of /{o,u}w/ sequences. Coupled with this, Williams' (1971) dictionary lists few forms that show these segment sequences. Surprisingly, there is no restriction on such sequences with 'wh'.

To complicate matters further, there is yet another co-occurrence restriction in Maori (Williams 1971:xxxiii). This time, it involves the labial *vowels* /o/ and /u/, where the sequence */uo/ is prohibited morpheme internally. However, Bauer (1993:544) disputes this, claiming that *all* possible vowel-sequences occur in Maori. Indeed, Williams' dictionary does list a number of forms with the /uo/ sequence. However, they are conspicuously few in number, and there is good reason to think that they are phonologically marked: some are loanwords, which typically do not follow

[2] For an overview of the meanings of featural terms such as 'labial', see Clements & Hume (1995), Halle & Clements (1983), and Kenstowicz (1994).

usual phonological rules, and the others did have morpheme boundaries between the /u/ and /o/ at some point in the past.[3] From this, it is valid to claim that the sequence */uo/ is prohibited morpheme-internally.

The problem is obviously not as simple as it first seemed. In fact, there are now four restrictions that need to be explained:

(4) (i) *w{o,u}
(ii) * wh{o,u}
(iii) *{o,u}w
(iv) *uo

The */uo/ restriction is significant in that it shows that the prohibition on adjacent labial continuants is not limited to CV configurations. In fact, the explanation of this co-occurrence restriction will give significant insight into the workings of the other restrictions.

The other prohibitions suggest that 'wh' and /w/ are related since they are prohibited in the same environment – i.e. before labial vowels. However, they must also be formally distinct since only /w/ is prohibited after /u/ and /o/. Of course, any formal distinction between /f/ and /w/ relies on a formal definition of their internal structure (or featural composition). For 'wh' this is not as simple a matter as one might think.

2.1 'Wh'

'Wh' represents the most dialectically variable sound in Maori. While it is difficult to determine the pre-European form of this phoneme, the use of the digraph 'wh' instead of 'f' suggests that the sound was not labio-dental, but perhaps voiceless and bi-labial. The dialectical reflexes of this sound vary somewhat, but still have features in common, as shown by the following list (summarising Bauer 1993:531,532):

(5) (i) [f]
(ii) [ʍ], a voiceless labio-velar fricative.
(iii) [h], strongly labialised, with back tongue raising.
(iv) [ʔw]
(v) [hw]/ [wh]

---

[3] It is difficult to be sure if modern native speakers still recognise the morpheme boundaries. Even so, it is conspicuous that /uo/ never occurs in an unambiguously mono-morphemic form from both a diachronic and synchronic point of view. The examples from Williams (1971) with related morphemes are: *kuoro* 'grind' cf *oro* 'grind', *puoro* 'song' cf *oro* 'sound', *puoto* 'vessel'—from English 'boat', *tuohu* 'stoop' cf *ohu* 'stoop', *tuoma* 'hasten' cf *oma* 'run', *tuone* 'gesticulate' cf *onetu:* 'speech', *tuora* 'a rite' cf *ora* 'a curse', *tuoro* 'a monster' cf *oro* 'rumble, be annihilated', *tuota* 'a type of charm' cf *otaota* 'a wand to which the mana [power] of a dead man was transferred.'

The common component of all the dialectical reflexes is the use of the lips to form at least part of the sound. This suggests that the phonological feature [labial] is common to them all. In addition, all forms include a voiceless component (realised in some as /h/ and /ʔ/) and all contain a continuant component (/f ʍ h w/). So, it is enough to idealise the situation and assume that 'wh' contains the features [labial], [+continuant] and [-voice]. Because of this, 'wh' will be represented as phonemic /f/, with the proviso that this makes no claim as to its precise phonetic realisation.

2.2 The Phonemic Conflation Approach

It is intuitively implausible that the restrictions in (4) are unrelated, existing as entirely separate phonological prohibitions. Because of this, a more fundamental constraint must be involved in the co-occurrence restrictions than can be expressed by a merely descriptive statement or rule such as in (4).[4]

One approach to reducing the number of restrictions is to claim that phonemic identity plays a role; after all, if the elements involved are allophones of a single phoneme then at least two of the co-occurrence restrictions can be conflated.

The most likely candidates for such a phonemic conflation are the glide /w/ and the vowel /u/ as they are featurally identical.[5] However, it is soon evident that these forms are not in complementary distribution as they appear in identical environments[6,7]:

(6)	ua 'backbone'	wa: 'region'
	uira 'gleam, flash'	wiri 'tremble, shiver'
	uere *Baryspira australis*	were 'hang, be suspended'
	pa:ua 'basin'	pa:wai 'collar-bone'
	pawa 'smoke'	koua 'roe of fish'
	kouaha = koua	kowaka 'dry, open gully'

[4] There is a more compelling reason to search for an underlying motivation for these restrictions – parsimony. If it is assumed that the grammar aims for parsimonious representation and computation, then it should maximise the resources it has, thereby conflating rules and processes.

[5] The feature [+syllabic] does not figure in the representation of /u/ (Levin 1985). Instead, all vowels have a preattached mora (Hyman 1985, Hayes 1989, Inkelas 1994, Perlmutter 1995).

[6] Although I only have six examples here, there are many more. For example, there are 33 words beginning with /uV/ alone in Williams' dictionary. By conventional approaches to /w/-/u/ allophony, all /uV/ sequences should be realised as /wV/.

[7] One reviewer pointed out that despite the claim that Maori spelling is phonetically transparent it is often difficult to tell whether a Maori word contains a [w], a [u], or a [o]. In many cases this is true but in others the difference is phonetically evident. Bauer (1993:540) points out that for many speakers /wa/ is pronounced [wɒ] whereas /ua/ is pronounced as either [ʉə] or [ʉɒ]. This phonetic difference offers at least some support for William's examples.

Similarly, /w/ and /f/ must be phonemically distinct as they also appear in identical environments, as do /f/ and /u/.

(7)	wa: 'area, region'	fa: 'four'
	wai 'water'	fai 'possessing'
(8)	uere 'univalve moluscs'	fere 'overcome'
	uara 'desire'	fara 'be struck'

From this, it is evident that an appeal to allophony is misguided.[8] Any attempt to provide an analysis must instead consider the featural content of the phonemes involved.

3. Towards a Resolution

So far, it has been established that any explanation of the co-occurrence restrictions involving /f/ and /w/ must account for the following facts:

(9) (i) *{w,f}{o,u}
(ii) *{o,u}w
(iii) {o,u}f
(iv) h{o,u}
(v) p{o,u}

(i) and (ii) restate the co-occurrence restrictions while (iii) makes the point that there must be some featural difference between /w/ and /f/ that motivates their different treatment with regard to preceding labial vowels. (iv) and (v) show that neither the feature [labial] alone (as in /p/) nor [+continuant] alone (as in /h/) is enough to cause a prohibition – the segment must be *both* [labial] and [+continuant].

However, this assumes that the features [labial] and [+continuant] are actually specified for /f/ and /w/ in the lexicon, or at least in the computational component of the phonology. A lack of such specification has significant implications for an adequate explanation of the problem. In fact, identifying the lack of underlying featural specification – or 'underspecification' – will be an essential step towards providing an economical solution to the co-occurrence restrictions.

3.1 Underspecification

The term 'underspecification' refers to the principle whereby predictable features of a phoneme are not specified in the lexical and computational component of the grammar. Instead, predictable features are inserted by redundancy rules after computation. The version of underspecification adopted here is that of Itô, Mester and Padgett (1995) since this framework

[8] Also see Hohepa (1967:6).

is particularly suited to Optimality Theory, which figures prominently in the latter part of this paper.[9]

Itô, Mester, & Padgett's framework relies on the notion of licensing (also see Itô & Mester 1993). This means that a segment does not contain a feature F if F is entirely predictable given the presence of some other feature – i.e. F is not *licensed* to apply underlyingly if it is predictable. For example, the feature [+sonorant] implies the presence of [+voice]; as such, [+voice] is not licensed by sonorants, and cannot be associated with a [+sonorant] segment underlyingly. However, a sonorant *can* be associated to [+voice] if that feature is licensed by and associated to *another* adjacent segment (see below). So, underspecification is the elimination of features in a phonemic inventory that are predictable by implication.

3.1.1 Feature Geometry

Underspecification plays an essential role in the Maori restrictions. However, determining the underspecified featural composition of a phoneme is impossible without being explicit about which phonological features exist.

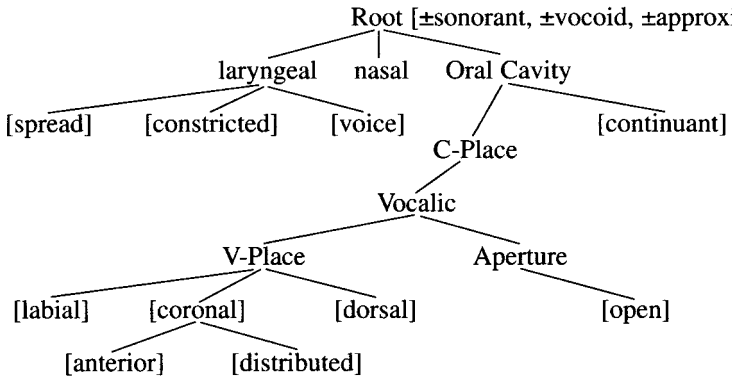
Earlier theories of featural composition treated phonemes as bundles of unordered phonological features (e.g. Chomsky & Halle 1968). This view was challenged by Clements (1985) and Sagey (1986)'s proposals that features are organised into dependency relations. For example, the feature [distributed] is dependent upon the node [coronal], which in turn is dependent upon the *place* node, and so on; without a [coronal] node, [distributed] cannot exist, and without a place node neither [coronal] nor [distributed] could exist in a representation. Only the outermost points of the tree – all those enclosed in square brackets in (10) – are features. These are called *terminal nodes*.

Recently, a consensus has emerged that features such as [±sonorant] and [±vocoid] are not terminal nodes, but are encased in the root node (Halle 1995, Clements & Hume 1995). Because of this, these features cannot enter into adjacency violations, nor can they spread independently of any other feature in the tree.

Clements & Hume (1995) have suggested another revision to featural organisation. They differ from other proposals in that their feature tree (or feature *geometry*) has a structural distinction between consonants and vocoids. The difference rests on the decomposition of the Place node into three separate nodes: C-Place, Vocalic, and V-Place. While all sounds have a C-Place node, only vocoids have a Vocalic and V-Place node. The diagram below shows the structure of a vocoid; a non-vocoid omits the Vocalic and V-Place nodes, with C-Place joining directly to the features [labial], [dorsal], and [coronal].

---

[9] The reader may also wish to examine other theories of underspecification (Kiparsky 1982, Archangeli 1984 cf Steriade 1995).



(10) *Amalgam of Consonant and Vocoid Trees*
[+/-] indicates bivalent features. All others are privative.
[Clements & Hume (1995:292)]

For the values of individual features see Clements & Hume (1995) and Halle & Clements (1983).

Some of the features are binary while others are privative. Binary features have two values, designated '+' or '-' (e.g. [+continuant]). Privative features have only one value and as such are either 'present' or 'not present'. As an example, the place features are all privative, so it makes no sense to say that a sound is [-labial], [+coronal], [-dorsal]. Instead, it is simply [coronal].

3.1.2 Maori Phonemes

From the theory of underspecification and the feature tree of Clements and Hume, the Maori phoneme inventory can be featurally decomposed in the following manner:

Root	*Phoneme*	*Labial*	*Coronal*	*Dorsal*	*Nasal*	*+Continuant*
-Approx	p	✓				
-Sonorant	t					
-Vocoid	k			✓		
	f	✓				✓
	h[10]					✓

[10] Some analyses have suggested that /h/ is [+vocoid] (Chomsky & Halle 1968:303, Halle 1995:7, Clements & Hume 1995:271). However, the evidence for this is not overly compelling (Fromkin 1970, Lass 1984), hence its representation here as a consonant. This has no significant implications for the analysis presented herein.

Root	*Phoneme*	*Labial*	*Coronal*	*Dorsal*	*Nasal*	*+Continuant*
-Approx	m	✓			✓	
+Sonorant	n				✓	
-Vocoid	ŋ			✓	✓	
	r					
+Approx	i					
+Sonorant	e					
+Vocoid	a					
	o	✓				
	u	✓				
	w	✓				

(11) Underspecified Maori phoneme inventory

The phonemes are not fully specified in the above table as many of their features are predictable by implication, and are therefore not licensed to appear. The following list gives the principal implications:

(12) (i) [α sonorant] → [α voice]
(ii) [α approximant] → [α continuant]
(iii) [+vocoid, labial] → [dorsal] (applies to /w, o, u/)[11]
(iv) [coronal] → [+anterior], [-distributed][12]
(v) [ ]$_{Place}$ → [coronal] (applies to /t, n, r, i, e/, but not to /h/ and /a/ since they have no place node)

The vowels are not specified for height features in (10). Although these are phonologically necessary to distinguish /i/ from /e/ and /u/ from /o/, they do not have any bearing on the present analysis as height features do not figure in any restrictions in Maori, with all vowel-combinations possible except */uo/.

This still leaves a distinction to be made between /w/ and /u/. A traditional approach to this would invoke the feature [±syllabic], with /w/ negatively specified for this feature and /u/ positively specified. A more recent idea is that vowels are underlyingly associated to a prosodic element called a mora, while glides are mora-less. This way there is no *featural* difference between /w/ and /u/, yet they are still distinct by virtue of their underlying prosodic affiliations.

A number of interesting facts follow from the characterisation of the

[11] This raises the classic problem of which feature implies the other : [dorsal] or [labial] (traditionally [back] or [round]). However, since [labial] is obviously the one involved in this co-occurrence restriction, it must be overtly specified.
[12] Since [anterior] and [distributed] are not contrastive features in Maori, [coronal] will be treated as the terminal feature (see Clements & Hume 1995).

phoneme inventory above. Firstly, apart from the nasals, /f/ is the only sound that requires the specification of two terminal features.[13] Such a featurally complex state is typically avoided or at least marked cross-linguistically (Padgett 1995) and will be shown to have a significant role to play in the Maori restrictions. Also, the place features used by vowels and consonants are identical. As such, [labial] is the same for the consonants /p, m, f/ and for the vocoids /w, u, o/, implying that they are accessible to each other for phonological processes (Hume 1992, Clements & Hume 1995). This also has significant repercussions in accounting for the co-occurrence restrictions.

3.2 Constraints and Feature Sharing

With the featural structure of the phonemes established, it is now possible to discern the workings of the co-occurrence restrictions.

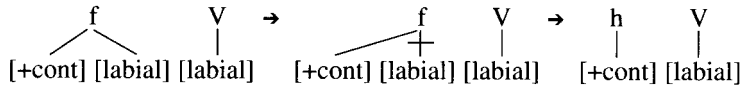
The co-occurrence restrictions in Maori seem to result from the Obligatory Contour Principle (OCP), which prohibits identical elements from being adjacent (Goldsmith 1976,1990; Myers 1994). The OCP was originally used to account for prohibitions on sequences of identical tones: i.e. *HH, *LL cf LH, HL. The OCP has since been extended to account for a wide variety of phonological phenomena, accounting for the avoidance of adjacent identical phonemes (McCarthy 1979), and at a lower level, the avoidance of adjacent identical features.

From (4) it is evident that the features involved in at least the /f{o,u}/ restriction are [labial] and [+continuant]. However, claiming that the OCP only holds for adjacent [labial] and [+continuant] features *together* and *not individually* is only restating the description in (4). Instead, let us assume that the OCP holds in its strongest form in Maori with the proviso that this will be revised shortly. In other words, adjacent identical features are prohibited.

(13) OCP: *FiFj.
(i) Fi and Fj are on the same tier.

There is more than one way to avoid an OCP violation. One method is to simply eliminate one of the features. This is arguably what has occurred in the diachronic change from Proto-Eastern Polynesian *f to Tahitian /h/ when followed by a round vowel (Biggs 1978, Harlow 1997):

(14)



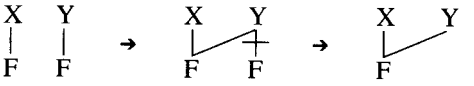
[13] Note that the root-contained features [±sonorant], [±approximant], and [±vocoid] are not terminal, and so do not figure in this statement.

To avoid an OCP violation one of the [labial] features must delink (thence delete), leaving /f/ with only its [+cont(inuant)] feature, effectively transforming it into the glottal fricative /h/.

The other method of avoiding the OCP is to share the offending feature:

(15) **SHARE**: 'Given a segment x and a segment y where x requires a feature Fi and y requires an identical feature Fj, then one of Fi,Fj is associated to both x and y, as long as x or y licenses F.'[14]

This is expressed representationally as:

(16) 

This way, instead of there being two adjacent identical features, one is delinked (thence deleted), and the other is associated to both segments.

Despite the seeming simplicity of this approach, there are a couple of complexities. 'Requires F' in the above definition means that a segment needs the feature F for full specification at the phonetic level.[15] For example, in the sequence /po/, /p/ and /o/ both require [labial] for full phonetic specification. However, just because a segment *requires* a feature F does not mean that it *licenses* F. For example, /n/ requires [+voice] for full specification. However, the feature [+voice] is predictable by implication, since all sonorants are voiced. Because of this, the [+sonorant] /n/ does not *license* the presence of the [+voice] feature.

Similarly, /p/ and /o/ both license [labial] since there is no feature in /p/ or /o/ which implies the presence of [labial]. As such, SHARE requires /p/ and /o/ to share this feature.

In comparison, the two sounds in the sequence /ou/ cannot share the feature [+continuant]; both require [+continuant] for full specification, but since this feature is implied by their [+approximant] root feature, neither can *license* its presence. Because of this [+continuant] cannot be associated to or shared by /ou/ in the computational system.

---

[14] This constraint follows from the system of Itô, Mester and Padgett (1995:10) whereby a constraint requiring the presence of a feature is ranked below one requiring the feature to be licensed. This formulation does not allow a segment sequence such as xyz to share a feature if only x licenses that feature. This may have to be broadened to include such a case, but this is a question beyond the scope of this paper.

[15] Despite the fact that a segment may *need* a feature for full specification, this does not imply that it will in fact be output from the phonological component fully specified.

The final case is where both sounds require a feature, but only one licenses it. For example, all vowels require [+continuant] but none of them license it. However, /f/ does license the presence of [+continuant]. Now, SHARE forces a feature F to spread if an adjacent segment *requires* F. So, in the sequence /fa/ even though /a/ does not license [+continuant], this feature still spreads from /f/ since /a/ *requires* it:

(17) 

One more matter has to do with *direction* of feature spreading. Many approaches to phonological processes have proposed that feature spreading – indeed all alterations in phonological representation – occurs from one edge to another in sequence. This directionality has often been seen as a parameter (see Archangeli & Pulleyblank 1994:298ff for discussion). In Maori, feature spreading occurs from left to right. So, in /uf/ only /f/ is associated to the feature [+continuant] despite the fact that /u/ requires it, simply because [+continuant] cannot spread leftwards.

3.2.1 Language-Specific Constraints

Having established that features must share when necessary, the exact constraints that cause the co-occurrence restrictions in Maori can be determined. The restrictions will be shown to result from constraints on the application of feature sharing in certain environments.

For Maori, there are two specific constraints that cause the co-occurrence restrictions. Firstly, the ban on */{o,u}w{o,u}/ sequences is caused by forcing an OCP violation of adjacent [labial]$^{\text{V-Place}}$ features:

(18) **LABSPR**: 'When [labial]$^{\text{V-Place}}$ is in an onset, it may not be shared.'[16]

Effectively, this means that /w/ may never spread its [labial]$^{\text{V-Place}}$ feature. The implications of this can be seen in the sequences /wo/ and /wu/. Both /o/ and /u/ bear a [labial]$^{\text{V-Place}}$ specification, and by SHARE in a sequence /wo/ the phoneme /w/ must share its [labial]$^{\text{V-Place}}$ feature with /o/. However, doing so violates LABSPR; alternatively, not doing so violates SHARE since there are two adjacent identical features. This produces a no-win situation, with either SHARE or LABSPR being violated. Ultimately, this means that /w{o,u}/ may

[16] More generally, when *any* V-Place feature is in the onset, it may not spread since /w/'s [labial] feature is the only V-Place feature that ever occurs in an onset. This may have something to do with licensing of V-Place features by the nucleus of the syllable. I will assume the more basic analysis for the moment. An 'onset' is the part of a Maori syllable that contains the consonant.

never be out-put from the phonological component. For detailed explanation of this point see section 4.

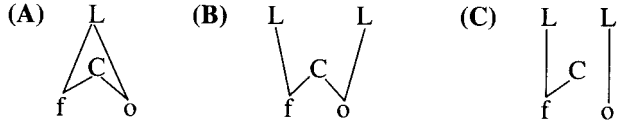
In comparison, LABSPR does not stop /ou/ from sharing the [labial] feature as neither /o/ nor /u/ are in an onset. At this point, the formulation of LABSPR may seem overly specific, but it will be shown to derive from broader principles.

3.2.2 */f{o,u}/

The */f{o,u}/ restriction is another matter. In this case, a prohibition is operative that is similar to LABSPR, but more general in scope:

(19) **SPRONS**: 'A segment in an onset and an adjacent segment may share only one feature.'[17]

This constraint is somewhat convoluted, but like LABSPR it can be shown to derive from general principles. Without further discussion as to its validity for the moment, it is evident that this will result in a prohibition of */f{o,u}/ sequences:



(20)[18] The */fo/ restriction
L = [labial], C = [+continuant]

In the examples above, /f/ licenses both [labial] and [+continuant] features whereas /o/ licenses only [labial] but *requires* both [labial] and [+continuant]. In (A), SPREAD has applied maximally, resulting in two shared features. This configuration is unacceptable as it causes a violation of SPRONS, which only allows one shared feature.[19]

In comparison, (B) satisfies SPRONS, permitting only one feature to

---

[17] Note that 'feature' only refers to terminal features. It does not refer to the root-contained features [±sonorant], [±approximant], and [±vocoid]. If this was not so, the sequences /mo, mu/ would be violations of SPRONS since they would share both [labial] and [+sonorant]. /mo/, /mu/, etc. are not prohibited since they share only the [labial] feature with the following vowel.

[18] Configurations of the type such as 19B with L replaced by C and vice-versa are impossible as C is not licensed by /o/. A similar explanation prohibits a 19C configuration with interchanged features.

[19] No other consonant will share two features with the following vowel. The only other two-featured phonemes are the nasals, and their [nasal] feature will never spread since there are no nasal vowels.

spread. Even so, now the OCP is violated because there are two adjacent [labial] features.

Finally, in (C) no feature has spread violating SPREAD as well as the OCP. Thus, /f/ is in a no-win situation when followed by a labial continuant. This effectively prohibits /f{o,u}/ sequences.

This raises an issue with respect to /{u,o}f/ sequences: should these not be prohibited by SPRONS? The reply to this is in the negative as feature spreading is rightwards. So, /u/'s [labial] feature will spread rightwards to join to /f/, but /f/'s [+continuant] feature cannot spread *leftwards* to /u/. So, /uf/ has only one shared feature, so satisfying SPRONS.

At this point, the two constraints SPRONS and LABSPR have accounted for the co-occurrence restrictions involving /w/ and /f/. However, the */uo/ restriction still remains.

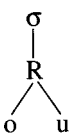
3.2.3 /uo/

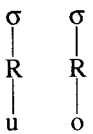
Superficially, the prohibition on /uo/ sequences seems to be related in some way to the restriction */{o,u}w{o,u}/ as it involves [labial]$^{\text{V-Place}}$. This relation will be shown to be more than co-incidental.

Of immediate concern is that the sequence /ou/ is permitted. Like LABSPR, it seems that [labial]$^{\text{V-Place}}$ must be blocked from spreading in certain configurations, forcing an OCP violation.

The problem is in defining the domain in which [labial]$^{\text{V-Place}}$ may not share. For /{o,u}w{o,u}/ the domain is between vowels and consonants. However, */uo/ prohibits [labial]$^{\text{V-Place}}$ from sharing between two vowels. However, a generalisation employing this cannot be valid since the sequence /ou/ is perfectly acceptable, and here [labial]$^{\text{V-Place}}$ *is* shared between two vowels.

This problem can be avoided by rejecting the linear characterisation of domains, appealing instead to prosodic structure. In this case it is syllabic structure that is significant. So, there must be a structural distinction between /ou/ and /uo/. Following previous work on syllable structure in Maori, the difference can be represented as in (21) (de Lacy 1995, 1996a,b; Barbour 1995):[20]

(21) /ou/: 

cf /uo/: 

Here, 'σ' represents the syllable node, while 'R' is the rime – a sub-syllabic constituent containing the vocalic members of a syllable. Whereas /ou/ is

[20] For a full discussion of syllable structure in Polynesian languages, see de Lacy (1997). The Maori syllable has the form (C)V(V).

contained in a single syllable, /u/ and /o/ are in separate syllables.[21] In other words, a diphthong in Maori is a sequence of two vowels where the second is less sonorous than the first. So, there are no 'rising' diphthongs in Maori (for discussion see Bickmore 1995 in the context of Tahitian). Thus, the /uo/ restriction can be stated as follows:

(22) LABSPR$: [labial]$^{V\text{-}Place}$ may not spread over a syllable boundary.

3.2.4 Implications

So far, two constraints have been identified that account for the /{o,u}w {o,u}/ and the /uo/ prohibition: LABSPR and LABSPR$. Returning to underspecification can simplify this even further.

There are a variety of processes in Maori that point to [coronal] as being the underspecified place of articulation in Maori. These include epenthesis in the passive suffix (Blevins 1994, Sanders 1991, de Lacy 1996b) and consonant dissimilation (Kawasaki 1988).[22] The implications of this are of some significance: since [coronal] is the default place of articulation feature, it need not be specified underlyingly, but filled in at the end of the derivation/computation. This means that any vowel with an empty Place node will be automatically assigned the feature [coronal].

So, /t/ can be specified underlyingly as having a C-Place node but no associated [coronal] feature since it will be supplied later.[23] In fact, /t/ cannot *license* the presence of [coronal] underlyingly because it is supplied by a redundancy rule. Similarly, /i/ and /e/ have a V-Place node and no features. This can be expressed representationally by the following redundancy rule:

(23) Place → Place
|
[coronal]

This results in a simplification of the featural composition of the vowels:

(24) /a/ = No Place node.
/e i/ = Place node, No features.
/o u/ = Place node, [labial] feature.

---

[21] Simply, if there are two adjacent vowels α and β, then α and β are in the same syllable if α is equally or more sonorous than β. Sonority is calculated according to the scale {/a/ > /e, o/ > /i,u/} (Dell & Elmedlaoui 1985). In the case of /aii/, it is syllabified as /a.ii/ (not /ai.i/) since long vowels take precedence over diphthongs. In /aei/ there are two possible combinations: /ae.i/ and /a.ei/. The former is chosen since syllabification is from left to right in Maori.

[22] Epenthesis in loanwords is a more complex issue. See Kearns (1990) and Kitto (in prep.).

[23] This is in contrast to /h/ which does not have a C-Place node at all.

This means that the only vowels with terminal features are /u/ and /o/, and that the only terminal feature for vowels is [labial].

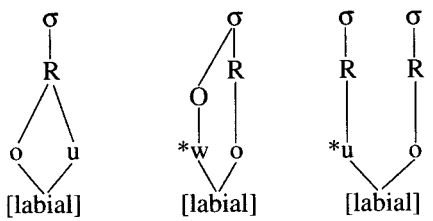
Now, the */uo/ and */{o,u}w{o,u}/ constraints state that [labial]$^{\text{V-Place}}$ can not spread in certain constituents. This can now be generalised to say that *no V-Place feature* may spread (in certain domains). This generalisation is possible since [labial] is the *only* V-Place feature specified underlyingly.

Even so, this still leaves two constraints:

(25) LABSPR: A V-Place feature may not share over an *onset* boundary.
LABSPR$: A V-Place feature may not share over a *syllable* boundary.

These two constraints can now be conflated into one by adopting a traditional model of the syllable which distinguishes between onset and rime (Halle & Vergnaud 1980):

(26)

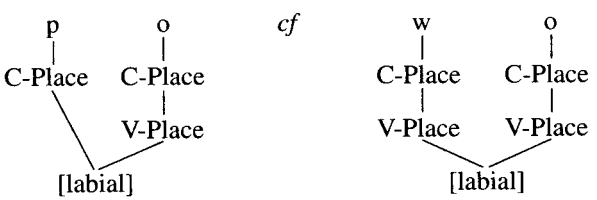


Here, the only situation in which [labial]$^{\text{V-Place}}$ can share is when the two sharing segments are in the same sub-syllabic constituent – i.e. the rime. So, LABSPR and LABSPR$ can be conflated into one constraint:

(27) V-SPR: V-Place features may not be shared over a sub-syllabic constituent boundary.

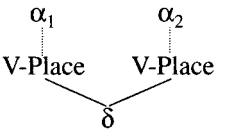
However, this leaves one issue unresolved. For example, in /po/, /p/ and /o/ both share [labial] features to avoid an OCP/SHARE violation. This is also true for /{f,m}{o,u}/. As it stands, V-SPR seems to prohibit such sharing. To avoid this, the term 'V-Place feature' needs to be refined. This is resolved by comparing /po/ and /wo/:

(28)



There is an obvious difference in the two configurations here. By employing this distinction V-SPR can be revised, and expressed representationally:

(29) V-SHARE: *



Prosodic tier

V-Place tier

terminal feature

δ is the terminal feature [labial]. The V-Place nodes must (ultimately) attach to two *different* prosodic nodes (α_1, α_2), hence being in separate sub-syllabic constituents.

Of course, this configuration does not occur in a /po/ sequence or in any other CV sequences (C ≠ /w/) since there is only one C-Place node and one V-Place node. In effect, the configuration only applies to /{o,u}w{o,u}/ and /uo/ sequences; it does not apply to other CV or VC sequences.

3.2.5 Linking

Up to this point, the restrictions involving /w/ have been the focus of attention, resulting in the constraint V-SHARE which prohibits both /uo/ and /{o,u}w{o,u}/ sequences. This still leaves the /f{o,u}/ prohibition which was ascribed to SPRONS (repeated here for convenience):

(30) SPRONS: A segment in an onset and an adjacent segment may only share one feature.

As it stands, SPRONS is overly specific and convoluted. It is possible to show that this constraint derives from more general principles.

Itô, Mester & Padgett (1995) postulate a set of Linkage constraints that prohibit certain segment sequences from sharing features. One example is NO-NC-LINK which prohibits feature-sharing between a nasal consonant and a following oral consonant. In the case of Maori, the constraint at work for */f{o,u}/ seems to be NO-CV-LINK. This prevents consonants and vowels sharing features in the configuration CV.

However, using NO-CV-LINK overpredicts: this means that C's and their following V's may *never* share a feature. This is plainly undesirable as there are many cases when this occurs in Maori (e.g. /m/ and /o/ share [labial], /f/ and /a/ share [+continuant]). A way to retain NO-CV-LINK is to allow it to be violated minimally without preventing the form from being out-put. However, traditionally no distinction has been made between differing *degrees* of constraint violation in phonological theory: a form fails if it violates one or several constraints.

More recent approaches to phonology have abandoned this view, allowing a distinction to be made between degrees of violation. One of the most successful approaches to this has been Optimality Theory (OT) (McCarthy & Prince 1993, Prince & Smolensky 1993). The following

sections introduce the basic tenets of OT, and offer an OT solution to the Maori co-occurrence problems in this framework.

4 Optimality Theory

Following traditional approaches to phonology, standard formulations of Optimality Theory recognise a repository for lexical items called the 'lexicon' (cf Hammond 1995). If a lexical item is to be output, it enters into a phonological component termed GEN. GEN generates a large number of possible output candidates from this input. From here, the output candidates enter a component called CON. In CON, the most optimal candidate is selected from all the possible outputs. This optimal candidate is then passed on to the phonetic component.

This raises a number of issues. Most importantly, there is the question of how optimality is calculated. In answer to this, CON consists of a set of universal constraints. These constraints are of two types – gradient and non-gradient. A gradient constraint can be violated more than once by an output candidate. For example, the constraint ALIGN(/V/, L, Wd, L) means 'align the left edge of a vowel with the left edge of a word'. So, the output candidate /CV/ violates this once while /CCV/ violates this constraint twice. In comparison, non-gradient constraints can only be violated once. If the ALIGN constraint above was non-gradient, both /CV/ and /CCV/ would incur only one violation.

To determine the optimal candidate of a set of possible candidates, it is only necessary to determine which candidate violates the least number of constraints.[24] As an example, consider the constraints ONSET, which requires every syllable to have an onset, and NO-CODA, which prohibits codas. A few possible outputs are given below, with their corresponding violations:[25]

(31)

	ONSET	NO-CODA
/at/	*!	
/tat/		*!
☞ /ta/		

The table shows that /at/ violates ONSET while /tat/ violates NO-CODA. Of the

[24] This does not mean that constraint violations are *counted*. See Prince & Smolensky (1993) for details.

[25] It is not possible to give *all* the possible outputs for a given input since there is an infinite number. Because of this, one must be rather selective with respect to candidate forms in an OT constraint tableau. However, this is of no significance in this paper since for co-occurrence restrictions it is only necessary to show that the prohibited input can never be output – i.e. that there is some more optimal output than it (see below for further discussion).

three candidates, /ta/ violates the least constraints, and hence is the most optimal form (marked by '☞'). Violations that were crucial in failing a candidate are marked by '!'.

There is an added complication to this system: constraints can be ranked with respect to each other. At the moment, /at/ and /tat/ are equally optimal as they both violate one constraint. However, if *onset* is ranked higher than NO-CODA, /at/ will be less optimal than /tat/ since it violates a more significant constraint. So, if a candidate violates a highly ranked constraint, it is less optimal than a candidate that violates a lower ranked constraint. In illustration, consider the following constraint tableau. This consists of ONSET, and the constraint ALIGN(V, L, Word, L) which requires a vowel to be at the left edge of a word. Crucially, ONSET is ranked above ALIGN:

(32)

	ONSET	ALIGN(V,Wd)
☞ ta		*
at	*!	

Although both candidates cause only one violation, /ta/ is the most optimal since it violates a lower-ranked constraint than /at/.

As a note on the form of the table, a solid line separating two constraints indicates that the leftmost constraint is ranked more highly than the rightmost. A dotted line as in (31) indicates that the constraints are unranked.

Of significant interest is the fact that although /ta/ violates a constraint, it is still the optimal output. Thus, it is not necessary for a candidate to satisfy *all* constraints. Instead, a relative approach is taken: the optimal candidate causes the *fewest* constraint violations in comparison to all other candidates.

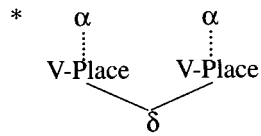
The OT framework places much significance on the formulation and ranking of constraints. Because of this, the following few sections are devoted to refining the constraints that have been proposed for the Maori co-occurrence restrictions so far. It will be shown an Optimality Theoretic approach significantly reduces the number of theoretical devices necessary to account for this problem while still offering the flexibility necessary to account for minor cross-linguistic differences.

4.1 Linkage

As mentioned above, the nature and form of constraints is of prime importance in an OT-oriented explanation. In this regard, Itô, Mester & Padgett's (1995) NO-*xy*-LINK family of constraints are of some use, and have a broad applicability. In effect, any elements can be x and y. For example, NO-CPLACE-VPLACE-LINK prevents a C-Place node from sharing a feature with a V-place node.

It has already been shown that the following configuration is prohibited:

(33)



This prohibition is really an amalgam of two constraints. The first is on the linking of V-Place elements: NO-VPLACE-LINK. The second is on the linking of two sub-syllabic constituents: NO-SUB$-LINK. /w{o,u}/, /{o,u}w/, and /uo/ violate both of these constraints as they share the feature [labial] between two V-Place nodes and between two different sub-syllabic constituents (i.e. onset and rime for /{o,u}w{o,u}/, and rime and rime for /uo/). In comparison, /ou/ only violates NO-VPLACE-LINK as [labial] is shared between two V-Place nodes. This difference in violation is extremely significant, even more so when the /f{o,u}/ prohibition is considered.

4.2 */f{o,u}/ Revisited

Using only the two constraints NO-VPLACE-LINK and NO-SUB$-LINK it is possible to account for the /f{o,u}/ restriction. Firstly, it is noticeable that the sequences /fu/ and /fo/ both cause two violations of NO-SUB$-LINK as /f/ and the following labial vowel share two features: [labial] and [+continuant].

In comparison, /pu/ violates NO-SUB$-LINK only once since /p/ and /u/ only share the single feature [labial]. In fact, no other CV or VC combinations cause two violations.[26]

At this point, it is conspicuous that all the co-occurrence restriction combinations incur *two* constraint violations while every other possible combination incurs only *one* (e.g. /po/) or even *none* (e.g. /tu/).

A method of prohibiting a sequence in an Optimality Theoretic framework is to arrange the constraint so that the input is never the optimal output. So, for the input /fu/, if the output candidate /hu/ is more optimal than the output candidate /fu/, /fu/ can never be out-put. From this, it is only necessary to show how it is that the input /f{o,u}/, /{o,u}w{o,u}/ and /uo/ can never be output intact. To do so requires a brief excursus into correspondence.

4.3 Correspondence

While, a number of constraints have already been established, two more are necessary to provide a workable Optimality account of the co-occurrence

[26] In /of.../ and /uf.../ there is only one violation since /u,o/ and /f/ share only[labial]. They do not share [+continuant] as features only spread rightward.

restrictions: IDENT(F^{IO}) and MAXIO (McCarthy & Prince 1995). These require a relation of *correspondence* to exist between the input form and a given output candidate.

MAXIO stipulates that every element in the input must have a corresponding element in the output. This constraint is necessary to prohibit an input being output as something totally unrelated, such as the input /tapa/ being output as /kimi/. Of course, there are no corresponding phonemes in the set /tapa/ and in /kimi/, causing multiple violations of MAXIO.

IDENT(F^{IO}) is somewhat more specific, requiring that for some *feature* or *set of features* in the input, there must be a corresponding feature in the output. For example, IDENT([labial]) requires that for every [labial] feature in the input there must be a corresponding [labial] in the output. So, with an input such as /p/ and an output /m/, IDENT([labial]) is not violated since /p/ and /m/ both have a [labial] feature. However, if the output was /t/, ident([labial]) would be violated since /t/ has no [labial] feature.

In Maori, both MAXIO and IDENT(F) will be used. However, IDENT(F) will only refer to C-Place features, hence IDENT(C-Place). This requires that for every C-Place configuration in the input, there must be a corresponding C-Place configuration in the output.[27]

At this point a simplification can also be made in the constraint system: So far both Spread and the OCP have been used, but they are essentially composites of each other; spread is violated in every case that the OCP is violated. More specifically, two adjacent identical features will cause an OCP violation and a spread violation. Since the OCP's role is subsumed by spread the OCP can be eliminated from the constraint ranking.

4.4 The Constraint System

So far, the following constraints have been invoked: NO-VPLACE-LINK, NO-SUB$-LINK, IDENT(C-Place), MAXIO, and SPREAD. As noted above, one of the crucial aspects of an OT constraint system is the constraint-ranking. Now, as it stands /fu/ can avoid violation of NO-VPLACE-LINK and NO-SUB$-LINK by simply not sharing its features. To force feature sharing, SHARE must be ranked above all other constraints.

In addition, MAXIO is ranked below all the other constraints for reasons that will become evident. This gives the following constraint ranking:

---

[27] More technically, take 'C-Place' to be a set of dominance relations involving the C-Place node (e.g. {(C-Place, [labial]),(C-place, [coronal])}. Hence for every set of relations involving C-Place as the dominating argument, there is a corresponding set of relations in the output. This is significant when considering sequences like /pu/. Here, in the input both /p/ and /u/ have the feature [labial]. However, in the output they are sharing [labial], hence there is one less [labial] feature in the output as there was in the input. Even so, this does not violate ident(C-Place) since the *relations* (/p/,C-Place,[labial]) and (/u/,C-Place,V-Place,[labial]) still exist in the output.

(34) SPREAD ≫ NO-VPLACE-LINK, NO-SUB$-LINK, IDENT(C-Place) ≫ MAXIO

All that remains is to show that these constraints are enough to prohibit all the co-occurrence restrictions while permitting licit forms. This is best demonstrated by considering the tableaux in the following section.

4.4.1 Tableaux

The tableaux have the following characteristics: the constraints are arranged in columns. If a dotted line separates two constraints, they are equally ranked. However, if there is a solid line, the leftmost constraint is ranked higher than the rightmost. A crucial violation of a constraint – i.e. a violation that eliminates a candidate – is marked with an exclamation mark '!'. Constraints that are irrelevant in determining the optimal output are darkly shaded. The most optimal candidate is marked with a pointer '☞'. In some cases there is more than one optimal candidate, hence more than one pointer.[28] Finally, an 'x' indicates that a candidate violates that constraint.

In the candidate representations below, the small 'l' represents the feature [labial] and 'c' represents [+continuant].

The first tableau shows the restriction on /f{o,u}/ sequences.

/fu/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
f u M LCL	x!		x			Spread is violated since [labial] is not spread.
f u ⋈ L C			x x!			
h u /| C L			x	x!	x	By using /h/ instead of /f/ a C-Place feature is lost.
☞ p u \/ L			x		x	Although [+continuant] is eliminated it is not a C-Place feature.
☞ m u \/ L			x		x	"
☞ t u / L				x	x	

(35) Tableau for the /f{u,o}/ restriction[29]

Here, it is only necessary to demonstrate that there is some sequence that is more optimal than /f{u,o}/. This means that /f{u,o}/ will never be out-put. In the above table, /pi/, /mu/, /tu/, and /iu/ are more optimal candidates than /fu/, hence /fu/ will never be output. Compare this with /{o,u}f/:

/uf/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
☞u f L C			x			[+continuant] does not spread leftwards.
u h L C				x	x!	By using /h/ instead of /f/ a C-Place feature is lost.
u p L			x		x!	Although [+continuant] is eliminated it is not a C-Place feature.
u t L				x	x!	/t/ is not /f/, violating MAXIO.
u L				x	x!	Elimination of /f/ violates both IDENT and MAXIO.
u o L		x	x!		x!	
i p L				x	x x!	
u i L				x	x!	

(36) Tableau for /{o,u}f/

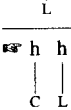
[29] The reader may be surprised to note that a possible candidate output from the input /fu/ is /tu/. However, if GEN is taken to generate all possible outputs from an input it will result in candidates that seem bizarrely divorced from the underlying form. By the above tableau, I am not suggesting that /pu/ and /tu/ are equally as optimal in this case. In this fragment of the Maori constraint hierarchy they are, but in reality there are other constraints that would mark them as non-optimal. We could ask, then, why it is not the case that nothing but /ta/, for example, can be produced, presuming that /ta/ is optimal in terms of markedness (a point made by Chomsky 1995). For a reply to this, see McCarthy & Prince (1995).

Unlike /f{u,o}/ the input /{o,u}f/ will always be out-put intact because there is no candidate that satisfies the constraints better. Every possible sequence violates at least one constraint in the constraint hierarchy. The most significant constraint in this respect is IDENT(C-Place) as any non-labial segment causes a violation. MAXIO is also significant as it makes a sometimes crucial distinction between the input and the output.

The following tableaux show that the sequences /{u,o}w/ and /w{u,o}/ can never be output.

/uw/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
		x	x!			
☞ 			x		x	
☞ 				x	x	Although [+continuant] is eliminated it is not a C-Place feature.
☞ 				x	x	

(37)Tableau for /uw/

/wu/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
		x	x!			
☞ 			x		x	
☞ 				x	x	Although [+continuant] is eliminated it is not a C-Place feature.
☞ 				x	x	

(38) Tableau for /w{o,u}/

Similarly, /uo/ incurs two violations, thereby never being optimal:

/uo/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
		x	x!			
☞ 				x	x!	

(39) Tableau for */uo/

Again, there is a more optimal output for every input of /uo/. It is interesting to compare this with /ou/, which incurs only one violation, and is more optimal than any other combination:

/ou/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
☞ 		x				
		x	x!		x x	
		x	x!		x	Although [+continuant] is eliminated it is not a C-Place feature.
				x	x!	

(40)Tableau for /ou/

The final two tableaux give examples of other consonant sequences to show that the constraints do not incorrectly prohibit licit forms. When a form incurs no violations, such as /tu/ and /ti/, it will be optimal since every other possible form will violate at least MAXIO.

/tu/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
☞ t u (L)						
n u (L)					x!	
u t (L)				x!	x x	Although [+continuant] is eliminated it is not a C-Place feature.

(41) Tableau for /tu/

/ti/	Spread	No-Vplace-Link	No-Sub$-Link	Ident (C-Place)	Max(IO)	Comments
☞ t i						
n i					x!	/n/ only has a [nasal] feature, as [coronal] is filled in by default.

(42) Tableau for /ti/

The tableaux demonstrate that the constraints SPREAD, NO-VPLACE-LINK, NO-SUB$-LINK, IDENT(CPLACE), and MAXIO are all that are necessary to account for the co-occurrence restrictions in Maori. This is a very economical solution since SPREAD and MAXIO are needed in the constraint system in any case (McCarthy & Prince 1995, de Lacy 1996a). This reduces the number of constraints specifically needed by the co-occurrence restrictions to three. The solution is also economical in that it utilises constraints that have been shown to be necessary elsewhere (Itô, Mester, and Padgett 1995, McCarthy & Prince 1995, de Lacy 1996a). Thus, the aim for computational parsimony is maximised by using an Optimality Theoretic approach.

This is not the only advantage in using Optimality Theory. Languages related to Maori have similar restrictions with minor variations. It will be shown in the next section that these minor variations can be dealt with by making minor alterations to the constraint system proposed, thereby further validating the approach in this paper.

5. Historical Development and Related Restrictions

The above section claims that the co-occurrence restrictions in Maori are the result of the interaction of general constraints of correspondence and linkage. Significantly, the motivations behind the restrictions are slightly

different in the case of */f{o,u}/ and */{o,u}w{o,u}/. From a diachronic point of view, this can help explain various phonemic changes and similar restrictions in related languages.

Related co-occurrence restrictions occur in many Polynesian languages.[30] It is notable that in the Eastern Polynesian (EP) group, of which Maori is a member, every language has altered Proto-Polynesian *f to /h/ or /ʔ/ at least before round vowels (Harlow 1997, Biggs 1978). A similar change has occurred in several of the Outlier languages (Clark 1976). If these changes have been motivated by some language-internal pressure then the co-occurrence restriction */f{o,u}/ would be a likely candidate. However, this does not seem to be the case outside Eastern Polynesia. Tongan has many /f{o,u}/ sequences, as does Samoan, Tokelauan, Wallis and Futuna, Tikopia, and West Futuna.[31] As such, it is not evident that a restriction on adjacent labial continuants was in force before Proto-EP.

The other significant phoneme is Proto-Polynesian *w. This is realised as [v] in all but five languages : [w] in Maori, Moriori, Ka-pi-nga-ma-ra-ngi, and Hawai'ian, and [β] in Rennelese. There is also evidence of a co-occurrence restriction involving this phoneme in many non-EP languages as many of the relevant dictionaries show an extreme paucity of /vu/ sequences. There are considerably more forms with /vo/, but even this sequence seems to be disfavoured in most languages. Of all these, Tongan has the most extensive set of words with /v{o,u}/ sequences, but even then they are few. The outliers Nukuoro, Kapingamarangi, Luanguia, Tikopia, and West Futuna have very few /vu/ sequences, as do Wallis and Futuna. /vo/ sequences are not as rare, but obviously avoided. Samoan has a number of /vo/ forms, but few /vu/ sequences, and the related Tokelau language has similar patterns.[32]

This raises the question of whether the co-occurrence restrictions in Maori are the same as the restrictions that hold in these other languages. The principal difference between EP and non-EP languages is that there is no restriction on /f{o,u}/ sequences while there is a restriction on /v{o,u}/ sequences.[33] In these cases, the restrictions cannot be broadly formulated as

---

[30] All reconstructed proto-phonemes in this section are taken from Clark (1976, 1992). The possible pre-Polynesian antecedents of the restrictions will not be discussed here — the focus will be on Polynesia.

[31] Sources for the languages cited here are listed in 'References Part II'.

[32] Of course, these claims are limited by the quality of the dictionaries used. In some cases the sources are very good (the cited cases), while in others there is inadequate information, and so cannot be cited here.

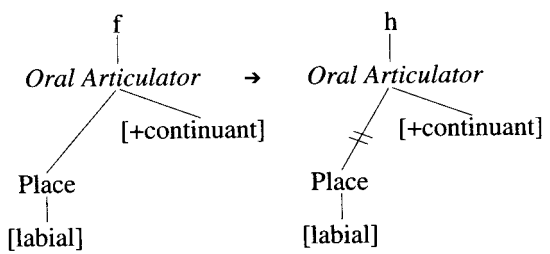
[33] This is assuming that the change of *f to /h/ or /p/ in several of the Outliers is not caused by a specific language-internal principle, but perhaps by a desire to simplify the segment internal configuration of their phonemes. Notably, *s ([+continuant], [coronal]) has also been avoided in this group of languages, suggesting that featural simplification is indeed the motivating force here.

applying to adjacent labial continuants. However, if a solution to this follows the suggestions in this paper it is significant that the most avoided sequence (/vu/) is featurally unique in comparison with other CV sequences. Notably, /v/ must be specified as [+continuant, labial, +voice], thus sharing three features with /u/ as /u/ is also a voiced labial continuant, violating NO-SUB$-LINK thrice. From this, it could be that these languages aim to avoid extensive feature sharing between segments; /fu/ is acceptable because it shares only two features, but /vo/ and /vu/'s sharing of three is a computational effort best avoided. From here, the feature-sharing restriction seems to have intensified even more in EP languages, allowing only one feature to be shared.

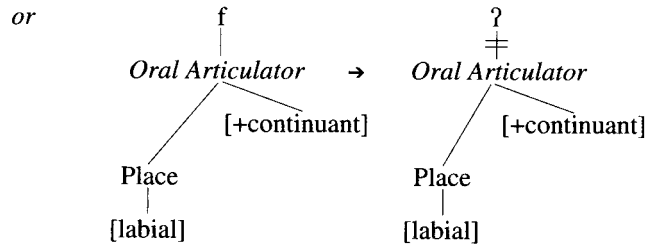
As noted above, many EP languages have altered the PEP phoneme *f to /h/ (Easter Island, Hawai'ian, Penrhyn) or /ʔ/ (Mangareva, the Austral Group, Cook Islands Maori). The others (i.e. Marquesic, Tahitian, Tuamotuan, Manihiki, Moriori)have variable reflexes of *f, most preserving it as /f/ except before round vowels when it is realised as /h/ (esp. Tahitian, see Harlow 1997). Given that there seems to have been some pressure for languages to alter their phonemes, the /f{o,u}/ restriction in Maori was probably active at some stage during the development of Proto-EP to its daughter languages. Supposing that this original restriction militated against elements that shared more than one feature, the elements with more than one featural specification were then /f/ and /v/, both specified for [labial] and [+continuant], with /v/ having an additional [+voice] specification. This restriction is still active in Tahitian's restriction on /f{o,u}/ and /v{o,u}/ sequences.[34]

The alternative was to simply eliminate featurally-complex phonemes altogether. The easiest way to alter the multi-featured /f/ was to delink a featural *set*. This was either the Place set, which resulted in the placeless continuant /h/, or the Oral Articulator node, resulting in a placeless stop /ʔ/:

(43)



[34] Exceptions for this language do exist; however they are very few in number (Jaussen 1993, Davies 1851).



The other option, largely avoided, was to delink the feature [+continuant] alone, resulting in /p/.

As for as the PPN reflexes of *w, Maori, Hawai'ian and Moriori are distinctive in having /w/, other EP languages have /v/. Unlike /f/, /v/ seems to have proven difficult to simplify featurally. If the C-Place node was delinked this would result in a highly marked sound – a voiced glottal continuant (/ɦ/).[35] If the Oral Cavity group was delinked, this would result in a voiced glottal stop (an articulatory impossibility). Hence, /v/ did not lend itself to change. The other option was to convert its root features to [+vocoid, +sonorant, +approximant], resulting in /w/ (Maori, Hawai'ian, Moriori).

A final option was to delink the [+voice] and [+continuant] features, resulting in /p/. However, this is a complex operation, and so was avoided.

5.1 Theoretical Considerations

The preceding discussion has shown that many languages related to Maori have similar restrictions, with minor variations. This is significant from a theoretical point of view for a number of reasons. Firstly, the restrictions in the related languages should be explainable in the same terms as Maori. However, different languages exhibit different combinations of restrictions. Many, for example, do not have the */uo/ restriction (i.e. all except Maori, Pehrhyn, and Easter Island). This small difference should ideally be expressed by a small alteration in the constraint system. If this is possible, it lends support to the approach in this paper.

Firstly, consider the */uo/ restriction. While a number of languages have the /f{o,u}/ and /v{o,u}/ restrictions only Easter Island and Penrhyn have the */uo/ restriction (du Feu 1996 and Yasuda 1968 resp.).[36] Of course, the lack of a */uo/ restriction requires a slightly different explanation from that used for Maori. In fact, accounting for this requires only one constraint

[35] See Chomksy & Halle (1968) for a discussion of phonological markedness.

[36] It is quite possible, even expected, that other languages prohibit this sequence. However, these are the only two for which definite statements to this effect were found.

alteration: instead of using NO-SUB$-LINK, the constraint is made slightly more specific, to NO-ONSET-RIME-LINK. This constraint prohibits feature sharing between an element in a syllable onset, and one in a syllable rime (the rime need not follow the onset). This is not violated by /uo/ since the [labial] feature is *not* shared between an onset and a rime, but between two rimes. In fact, the only forms that do violate NO-ONSET-RIME-LINK are */f{o,u}/ and */{o,u}w{o,u}/.

It seems that some other languages (perhaps most) do not have the /{o,u}w/ restriction. Again, this only requires a minor alteration to the constraint system. NO-ONSET-RIME-LINK is again used, but with one further restriction: the onset and rime must be in the same syllable. This means that /{o,u}w/ sequences will not violate this constraint, since the rime and onset are in different syllables.

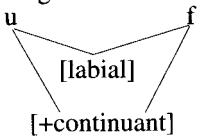
Another variation relates to Maori itself. It seems that there is (or was) a rule optionally prohibiting /{o,u}f/ sequences (Bauer 1993:564). In such sequences, the /f/ would become /h/:

(44) uwha ~ uha 'female' uwhi ~ uhi *dioscorea*
owha ~ oha 'greet'

At issue here is the prohibition of /{o,u}f/ sequences, so I will not attempt to explain how the output with /h/ came to be the most optimal form.

Preventing the /{o,u}f/ output again requires only a minor alteration to the Maori explanation. All that is needed here is for this sequence to incur two violations. An easy way of achieving this is to force it to share its two features [labial] and [+continuant] with the preceding vowel. To achieve this, all that is needed is for the directional restriction on feature spreading to be relaxed, so as to allow bi-directional spreading. This will result in the following configuration:

(45)



This violates NO-SUB$-LINK twice. Of course, a form such as /up/ will only cause one violation of the relevant constraints (i.e. not including MAXIO), and so be more optimal /uf/ and /of/. Thus, /{o,u}f/ will never be out-put given bi-directional feature spreading.

As such, it is evident that the minor differences in co-occurrence restrictions in related languages can be accounted for by minor alterations to the constraint system, further validating the approach in this paper.

6. Related Issues

6.1 Scope

A question which has not been addressed is the domain in which the co-occurrence restrictions hold. In the case of */uo/ the restriction only applies within the morpheme as a number of forms exist with this sequence over a morpheme boundary.[37]

The evidence is less clear for the */{o,u}w/ sequence. There are forms such as *hauwai* 'damp' which seems to be a compound from *hau* 'damp, moisture' and *wai* 'water', indicating that the distinction does not apply over a morpheme boundary. On the other hand, the word *hauware* 'saliva' (cf *hau* 'damp' and *ware* 'spittle') has the alternative forms *haware* and *huare*, both avoiding the /{o,u}w/ sequence. This time, however, the restriction seems to hold over a morpheme boundary.

For the other co-occurrence restrictions involving /f/ and /w/, the domain must be morpheme-internal as they involve consonant-vowel sequences. Since there no syllables that end in a consonant in Maori the consonant must be part of the same syllable as the vowel, which means that they must also be part of the same morpheme (there are no morphemes /w-/ or /f-/). In sum, the domain for these processes is necessarily the morpheme.

6.2 Productivity

A final note must be made on the productivity of the processes in question. Bauer (1993) notes that native speakers felt that loanwords with /{w,f}{o,u}/ sequences were awkward. This in itself is not proof of the productivity of this constraint. It could be merely recognition on the part of the speaker that the sequences are extremely rare, even non-existent, in the language and therefore marked but not necessarily prohibited. On the other hand, the existence of loanwords with the offending sequences in some dialects does not imply that there is no prohibition in force; Itô and Mester (1995) note that loanwords are often not subject to many phonological rules. As such, the question of productivity could only be answered by observing a massive influx of words with /{w,f}{o,u}/ sequences into EP languages. If these sequences changed over time as they became internalised this would be adequate evidence that the prohibition is active. However, it is extremely unlikely that such a situation will ever take place.

7. Conclusion

This paper has shown that the relations between the Maori co-occurrence restrictions are neither obvious nor trivial. In fact, it is only by addressing

[37] Again there is a question as to whether these are synchronic morpheme boundaries or not. If they are not, then this could mean that the restrictions applied at a time when these boundaries were recognised, but does not necessarily mean that the restrictions are still inactive in the language.

other issues in the language's phonology that the non-obvious nature of the co-occurrence prohibitions can be discerned.

A number of issues significant to the study of Polynesian phonology have also been discussed, particularly featural underspecification. For the study of phonology, this paper has shown that processes that promote parsimonious representation and computation play a pervasive role in the phenomena under consideration. Parsimony is promoted on all levels, most obviously at the featural level for underspecification, but also with respect to representation. Indeed, the constraint requiring feature spreading increases economy of representation by eliminating unnecessary features. In addition, this paper has affirmed the validity of Itô, Mester & Padgett's (1995) theory of underspecification, and the parallelist approach to phonological computation provided by Optimality Theory.

In sum, the co-occurrence restrictions in Maori are examples of how seemingly simple phonological phenomena can in fact be caused by the complex interaction of non-obvious constraints, and have implications for phonology in general.

NOTE: It was suggested that the Maori restrictions on */w{u,o}/ should be related to the Mandarin restriction on */u/, requiring [wu]. I do not see these as comparable from a number of points of view. Firstly, the Mandarin [wu] does not consist of two separate phonemes, but one: [w] is made up of material from the /u/. In comparison, Maori recognises the two distinct phonemes /w/ and /u/. In addition, the patterns of restrictions in Maori are far more complex than in Mandarin, also including */{u,o}w/, */f{o,u}/. One would expect any explanation of the Maori */wu/ restriction to at least relate to the other restrictions involving the features [labial] and [+continuant]. Because of these differences, I suggest that the Mandarin situation is not as analogous to Maori as it first seems.

Another suggestion in accounting for the Maori *wu restriction is that it is phonetically difficult to produce.[38] In recent concepts of functionalist phonology (Hayes 1996) this phonetic difficulty would give rise to a rule simply stating that /wu/ sequences are prohibited. While appealing to a phonetic motivation is *a priori* plausible, it is difficult to see how similar reasoning extends to the */fu/ restriction, and to the restrictions involving /o/. Also, I see no easy way that this sort of explanation can give a motivation for the consonant dissimilations. Because of this, I prefer to offer a phonologically-motivated approach involving abstract features. This better relates the *wu prohibition to the other restrictions.

[38] Thanks to Phillip Hamilton for raising this point. Also see Hayes (1989:300) for some discussion on *wu prohibitions.

References

Part I

Archangeli, Diana. 1984. *Underspecification in Yawelmani Phonology and Morphology.* PhD dissertation, MIT.

Archangeli, Diana and Douglas Pulleyblank. 1994. *Grounded Phonology.* Cambridge, Mass.: MIT Press.

Barbour, Juliette. 1995. 'A Reanalysis of Syllable Structure in Maori and Samoan.' M.A. Research Paper, University of Auckland.

Bauer, Winifred. 1981. 'Hae.re vs ha.e.re: A Note' *Te Reo* 24: 31-36.

Bauer,Winifred. 1993. *Maori.* London & New York: Routledge.

Bickmore, Lee S. 1995. 'Refining and Formalizing the Tahitian Stress Placement Algorithm.' *Oceanic Linguistics* 34: 410-442.

Biggs, Bruce. 1978. 'The History of Polynesian Phonology' in S.A.Wurm and Lois Carrington (eds.) *Second International Conference on Austronesian Linguistics: Proceedings.* pp.691-715. Fascicle 2 Eastern Austronesian. Pacific Linguistics c-61 ANU.

Biggs, Bruce (ed). 1996. 'POLLEX'. Computer Database of reconstructed Proto-Polynesian lexical items with their reflexes. University of Auckland.

Blevins, Juliette. 1994. 'A Phonological and Morphological Reanalysis of the Maori Passive'. *Te Reo* 37:29-53.

Buse, Jasper & Raututi Taringa. 1995. *Cook Islands Maori Dictionary.* Canberra: ANU Printing Services. (ed. Bruce Biggs & Rangi Moeka'a).

Catford, J.C. 1994. 'Articulatory Phonetics'. In R.E.Asher (ed) 'Encyclopaedia of Language and Linguistics.', pp.3058-3070, Exeter, Great Britain: Pergamon Press Ltd.

Chomsky, Noam. 1995. *The Minimalist Program.* Cambridge: MIT Press.

Chomsky, Noam & Morris Halle. 1991 [1968]. *The Sound Pattern of English.* Cambridge, MA.:MIT Press.

Clark, Ross. 1976. *Aspects of Proto-Polynesian Syntax.* University of Auckland: Linguistic Society of New Zealand.

Clark, Ross. 1992. 'Table of Polynesian Sound Correspondences.' Lecture Handout.

Clements, G.N. 1985. 'The Geometry of Phonological Features.' *Phonology* 2:225-252.

Clements, G.N. & Elisabeth Hume. 1995. 'Internal Organisation of Speech Sounds.' in John Goldsmith (ed.) *The Handbook of Phonological Theory.* pp 245-306, Oxford: Blackwell.

de Lacy, Paul. 1995. 'Polynesian and Fijian Stress Systems'. ms. University of Auckland.

de Lacy, Paul. 1996a. 'Circumscription Revisited: An Analysis of Maori Reduplication.' Rutgers Optimality Archive #133 (http:// www.ruccs. rutgers.edu /roa.html).

de Lacy, Paul. 1996b. 'The Structure of Lexical Entries and the Maori Passive Suffix.' ms. University of Auckland.

de Lacy, Paul. 1997. 'The Prosodic Structure of Cook Islands Maori.' ms. University of Auckland.

Dell, Francois & Mohamed Elmedlaoui. 1985. 'Syllabic Consonants and Syllabification in Imdlawn Tashlhiyt Berber.' *Journal of African Lgs & Linguistics* 7:105-130.

Fromkin, Victoria. 1970. 'The concept of naturalness in a universal phonetic theory.' *Glossa* 4:29-45.

Goldsmith, John. 1976. *Autosegmental Phonology.* PhD Thesis. MIT.

Goldsmith, John. 1990. *Autosegmental and Metrical Phonology*. Cambridge, MA.: Basil Blackwell.
Halle, Morris. 1995. 'Feature Geometry and Feature Spreading.' *Linguistic Inquiry* 26.1:1-46.
Halle, Morris & G.N. Clements. 1983. *Problem Book in Phonology*. Cambridge, MA: MIT Press.
Halle, Morris & J.R. Vergnaud. 1980. 'Three Dimensional Phonology.' *Journal of Linguistic Research* 1:83-105.
Hammond, Mike. 19 Jan 1995. 'There is no lexicon!' University of Arizona.
Harlow, Ray. 1997. '*f and *s in Eastern Polynesian.' Paper presented at the Third International Conference on Oceanic Linguistics and Pacific Contact Linguistics Association.
Hayes, Bruce. 1989. 'Compensatory Lengthening in Moraic Phonology.' *Linguistic Inquiry* 20:253-306.
Hayes, Bruce. 1996. 'Phonetically Driven Phonology: The Role of Optimality Theory and Inductive Grounding.' Rutgers Optimality Archive.
Hohepa, P. 1967. *A Profile Generative Grammar of Maori*. Bloomington, Ind.: Indiana University Press.
Hume, Elizabeth. 1992. 'Front Vowels, Coronal Consonants, and their Interaction in Non-Linear Phonology.' PhD Dissertation. Cornell University.
Hyman, Larry. 1985. *A Theory of Phonological Weight*. Dordrecht: Foris.
Inkelas, Sharon. 1994. 'The Consequences of Optimization for Underspecification'. Rutgers Optimality Archive.
Itô, Junko & Armin Mester. 1993. 'Licensed Segments and Safe Paths.' in C.Paradis & D.LaCharité (eds). *Constraint-Based Theories in Multi-Linear Phonology, Canadian Journal of Linguistics* (Special Issue) 38:197-213
Itô, Junko & Armin Mester. 1995. 'Japanese Phonology.' in John Goldsmith (ed). *Handbook of Phonological Theory*. pp. 817-838, Oxford: Blackwell.
Itô, Junko, Armin Mester and Jaye Padgett. 1995. 'NC: Licensing and Underspecification in Optimality Theory.' *Linguistic Inquiry* 26.4
Kawasaki, N. 1988. 'Cooccurrence Restrictions on Consonants in Some Polynesian Languages'. *University of Massachusetts Occasional Papers* 13.
Kearns, Kate. 1990. 'A Note on the Glottal Fricative in Maori.' *Te Reo* 33:65-81.
Kenstowicz, Michael. 1994. *Phonology in Generative Grammar*. Cambridge, Mass.: Blackwell.
Kiparsky, Paul. 1982. 'Lexical Phonology and Morphology.' in S.Yang (ed). *Linguistics in the Morning Calm*. vol 2:3-91. Seoul, Korea: Hanshin.
Kitto, Catherine. in preparation. *The Phonology of Polynesian Loanwords*. MA Dissertation, University of Auckland.
Krupa, Viktor. 1966. 'The Phonemic Structure of Bi-vocalic Morpheme Forms in Oceanic Languages', *Journal of the Polynesian Society* 75:458-497.
Krupa, Viktor. 1968. *The Maori Language*. Moscow: Nauka Publishing House.
Krupa, Viktor. 1971. 'The Phonotactic Structure of the Morph in Polynesian Languages.' *Language* 47:668-684.
Lass, Roger. 1984. *Phonology: An Introduction to Basic Concepts*. Chicago University Press.
Laver, John. 1994. *Principles of Phonetics*. New York: Cambridge University Press.
Levin, Juliette. 1985. *A Metrical Theory of Syllabicity*. PhD dissertation, MIT.
McCarthy, John. 1979. *Formal Problems in Semitic Phonology and Morphology*. PhD Thesis, MIT.

McCarthy, John & Alan Prince. 1993. *Prosodic Morphology I.* Rutgers University, Technical Report #3.
McCarthy, John & Alan Prince. 1995. 'Faithfulness and Reduplicative Identity.' Rutgers Optimality Archive.
Myers, Scott. 1994. 'OCP Effects in Optimality Theory.' Rutgers Optimality Archive.
Padgett, Jaye. 1995. 'Feature Classes.' in J.Beckman, S.Urbanczyk & L.Walsh (eds), *Papers in Optimality Theory.* University of Massachusetts Occasional Papers 18:385-414, GLSA, University of Massachusetts at Amherst
Perlmutter, David. 1995. 'Phonological Quantity and Multiple Association' in John Goldsmith. (ed) *Handbook of Phonological Theory.* pp. 307-317, Oxford: Blackwell,
Prince, Alan & Paul Smolensky. 1993. *Optimality Theory.* Rutgers University, Technical Report #2.
Sagey, Elisabeth. 1986. *The Representation of Features and Relations in Non-Linear Phonology.* PhD Dissertation. MIT. New York: Garland Press, 1990.
Sanders, G. 1991. 'Levelling and Reanalysis in the History of Polynesian Passive Formations.' *Journal of the Polynesian Society* 100:71-90.
Steriade, Donca. 1995. 'Underspecification and Markedness.' in Goldsmith, John (ed). *Handbook of Phonological Theory.* pp.114-174. Oxford: Blackwell.
Williams, Herbert W. 1971. *A Dictionary of the Maori Language.* 7th edition. (orig. 1844). Wellington, N.Z.: A.R.Shearer, Government Printer.

Part II

Besnier, Niko. 1981. *Tuvaluan Lexicon.* U.S. Peace Corps.
Carrol, V. & T.Soulik. 1973. *Nukuoro Lexicon.* University of Hawaii Press.
Churchward, Charles M. 1953. *Tongan Grammar.* Oxford University Press.
Davies, John. 1851. *A Tahitian and English Dictionary.* Tahiti: London Missionary Society's Press.
Dordillon, R. 1931. *Grammaire et dictionnaire de la langue des Marquises.* Paris: Institut d'Ethnologie.
Dougherty, J.W.D. 1983. *West Futuna-Aniwa: An Introduction to a Polynesian Outlier Language.* University of California Press.
du Feu, Veronica. 1996. *Rapanui.* London & New York. Routledge.
Elbert, Samuel H. 1948. *Grammar and Comparative Study of the Language of Kapingamarangi, texts and word lists.* Washington: Report to the Pacific Science Board.
Elbert, Samuel, R.Kuschel & T.Taupongi. 1975, 1988. *Dictionary of the Language of Rennell and Bellona* [2 volumes]. National Museum of Denmark.
Englert, S. 1977. *Diccionario rapanui-español.* New York: AMS Press.
Feinberg, R. 1977-8. *The Anuta Language Reconsidered: Lexicon and Grammar of a Polynesian Outlier.* New Haven, Conn.: Human Relations Area Files.
Firth, R. 1985. *Tikopia-English Dictionary.* Auckland: Auckland University Press.
Fuentes, J. 1960. *Diccionario y gramatica de la lengua de la Isla de Pascua.* Santiago: Editorial Andres Bello.
Hollyman, K.J. 1987. *De muna fagauvea I: dictionnaire fagauvea-français.* Auckland: Linguistic Society of New Zealand.
Jaussen, Tepano. 1993. *Dictionnaire de la langue tahitienne.* Papeete: Société des études océaniennes.
Kuki, Hiroshi. 1970. *Tuamotuan Phonology.* Canberra: Pacific Linguistics B17.

Lemaître, Yves. 1973. *Lexique du tahitien contemporain*. Paris: Office de la Recherche Scientifique et Technique Outre-Mer.
Leverd, A. 1922. 'Polynesian Language of Uvea, Loyalty Islands.' *Journal of the Polynesian Society* 31:94-103.
McEwan, J.M. 1970. *Niue Dictionary*. Wellington: Department of Maori and Island Affairs.
Milner, G.B. 1966. *Samoan Dictionary*. Oxford University Press.
Moyse-Faurie, C. 1993. *Dictionnaire futunien-français*. Paris: Peeters.
Noricks, J. 1981. A Tuvalu Dictionary. New Haven, Conn.: Human Relations Area Files.
Pratt, G. 1911. *A Grammar and Dictionary of the Samoan Language.(4th ed.)* Malua, Samoa: London Missionary Society, Western Samoa.
Pukui, M. & Samuel Elbert. 1986. *Hawaiian Dictionary*. Honolulu: University of Hawaii Press (also 1957, 1971).
Ranby, P. 1980. *A Nanumea Lexicon*. Canberra: Pacific Linguistics C65.
Rensch, Karl H. 1986. *Dictionnaire futunien-français*. Australian National University.
Rensch, Karl H. 1984. *Tikisionalio Fakauvea-Fakafalani/ Dictionnaire wallisien-français*. Canberra: Pacific Linguistics C86.
Savage, Stephen. 1962. *A Dictionary of the Maori Langauge of Rarotonga*. Wellington: Dept of Island Territories.
Tregear, E. 1899. *A Dictionary of Mangareva (or Gambia Islands)*. Wellington, N.Z.: Government Printing Office.
Tregear, E. 1907. *A Vocabulary and Grammar of the Niue Dialect of the Polynesian Language*. Wellington: Government Printing Office.
Tsukamoto, A. 1988. *A Grammar of Niuafo'ou*. PhD Thesis, Australian National University.
Yasuda, A. 1968. *The Structure of the Penrhyn Phrase*. M.A.Thesis. University of Hawaii.