

A Squib on the Sound Patterns of Hawaiian^{*}

1. Consonant inventory, phonetic dispersion and allophony

Hawaiian has a very impoverished consonant inventory - only eight consonants, phonetically described in the following chart:

(1) Consonants

	Bilabial	Dental-alveolar	Alveolar	Velar	Glottal
Stop	p			k	ʔ
Fricative					h
Nasal	m	n			
Lateral			l/r		
Glide	w/v				

We see here that place of articulation is quite phonetically dispersed in that five places are used for only eight consonants, and three places are used for only one consonant each. In addition, the less-sonorous segments tend to be articulated more toward the rear of the vocal tract, while more-sonorous segments tend to be articulated more toward the front of the vocal tract.

The observation that obstruents tend to be realized toward the rear of the vocal tract is particularly striking because there is a conspicuous absence of what are usually called coronal obstruents (i.e. dental/alveolar/palatal). This has been a source of much interest among phonologists because of the assumption that the unmarked place of articulation is coronal. Interestingly, the descriptive literature on Hawaiian does claim that there is dialectal variation in the realization of the velar stop such that some speakers randomly substitute [t] for the velar stop. Although this may be partially systematic in the speech of some speakers (i.e. [t] tends to be found after [i]), the descriptions are clear in that [t] and [k] allophones are in free variation for others. None the less, researchers agree that the contrastive segment is /k/ and not /t/.

Another observation about consonants is that there is often ambiguity in the articulation of the bilabial glide, which varies in the amount of rounding by both speaker and context. Some speakers consistently use one or the other (at least at slower speech rates), while other speakers show phonetic variation based on the quality of the preceding vowel. The more rounded allophone appears after back round vowels [u] and [o], the less rounded allophone appears after front unrounded vowels [i] and [e], and either one may appear word initially or following a low vowel [a].

Finally, there are some speakers who sometimes pronounce the lateral like an “r”. However, it is unclear from Elbert & Pukui whether there are any conditioning factors to this allophony.

2. Consonant “substitutions” in the lexicon

Although the picture painted above for the consonant inventory seems quite simple, there are two types of dialectal lexical substitutions (diachronic lexical processes) involving consonants. First, [l] in some dialects tends to assimilate to [n] in some words containing

^{*} Based on the description of Elbert & Pukui (1979).

another [n]. This is not a regular phonological process and appears to be a property of the lexicon (more precisely, the acquisition of the lexicon). However, it is probably not an accident that it is only these two segments that participate in this “assimilation”. We might assume that the lateral and the non-labial nasal are similar in their feature composition and that the nasal has an extra feature that assimilates in this context. This will be demonstrated below.

Second, the lateral and the velar stop often surface as a glottal stop in selected words in certain dialects. Again, this does not seem to be a regular phonological process, but it does suggest that these three segments are featurally similar and that the glottal stop is the more basic of the three. This will be discussed and formalized below.

Hawaiian seems to have no true phonological processes affecting consonants.

3. Vowel inventory, phonetic dispersion and allophony

If we ignore vowel length, Hawaiian has a typical five-vowel system, phonetically described in the following chart:

(2) Vowels

	Front	Central	Back/ Round
High	i		u
Mid	e/ɘ		o
Low		a	

As one might expect, these vowels are maximally dispersed from a phonetic perspective in that the vowels showing a contrast along the front-back dimension use both tongue configuration and lip rounding to maximize their acoustic difference. In contrast, the one low vowel is central in the acoustic space since it is not in contrast along the front-back dimension and being central makes it more perceptually distinct from the non-low vowels, which are non-central.

That said, the actual phonetic realization of these vowels can change slightly depending on the prosodic and segmental context. The high vowels are slightly lower in unstressed syllables, while the low vowel is realized as slightly higher. The mid front vowel is more centralized when adjacent to a consonant made with an alveolar articulation ([l] or [n]). Both of these variations are consistent with known cross-linguistic phonetic tendencies and do not seem to be phonological in nature.

4. Vowel combinations (phonology)

Hawaiian allows for vowel sequences of two types: clusters and diphthongs. A vowel cluster is a sequence of two (non-identical?) vowels that when followed by a single syllable has stress on the second vowel in the sequence. [Are there any restrictions on the sequences allowed in clusters?] In contrast, diphthongs always have stress on the first element and are restricted in their membership. The first vowel of a diphthong must be phonetically lower (phonologically more sonorant) than the second. This results in four diphthongs containing the low vowel and two diphthongs each containing a mid vowel as the first element.

(3) Diphthongs

		Second V (unstressed)				
		i	u	e	o	a
First V (stressed)	i	--	--	--	--	--
	u	--	--	--	--	--
	e	ei	eu	--	--	--
	o	oi	ou	--	--	--
	a	ai	au	ae	ao	--

Hawaiian does not seem to have any phonological rules affecting vowels.

5. Phonological analysis (representational)

Given the phonetic and distributional facts, as well as the lack of obvious phonological interactions and alternations among segments, one might expect the Hawaiian phonological system to use a very limited and economical set of features and structures.

The following chart lists the segments and their phonological feature specifications using the Parallel Structures Model of feature geometry. As we will see, there are seven phonological features used - two place features, C-place[lab] and C-place[cor], three consonant manner features, C-manner[closed], C-manner[open] and C-manner[nasal], and two vowel manner features, V-manner[closed] and V-manner[open].

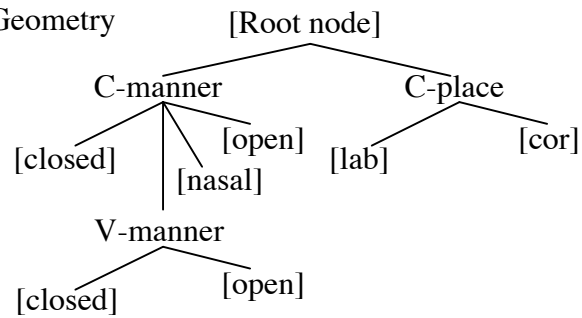
(4) Hawaiian segments defined by PSM features

Manner Description			C-lab	C-cor	C-closed	C-open	C-nasal	V-closed	V-open
Mannerless	/w/	[w/v]	✓						
	/l/	[l/r]		✓					
Stop	/ʔ/	[ʔ]			✓				
	/p/	[p]	✓		✓				
	/k/	[k/t]		✓	✓				
Fricative	/h/	[h]				✓			
Nasal	/m/	[m]					✓		
	/n/	[n]		✓			✓		
High	/i/	[i]						✓	
	/u/	[u]	✓					✓	
Mid	/e/	[e/ɛ]						✓	✓
	/o/	[o]	✓					✓	✓
Low	/a/	[a]							✓

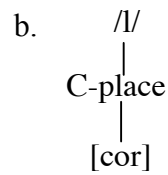
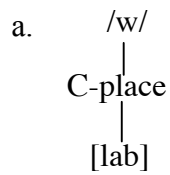
Note: Shaded cells indicate segments composed of only a single feature, including mannerless and placeless segments.

The fully specified representation is given in (5), and the representations of each segment are given in (6) through (12).

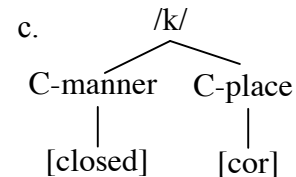
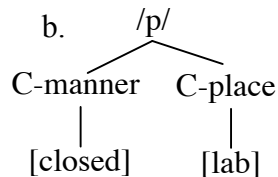
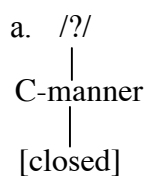
(5) Hawaiian PSM Geometry



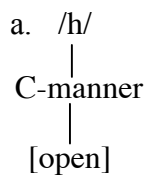
(6) Mannerless segments



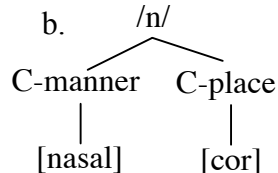
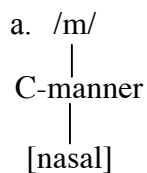
(7) Stop segments



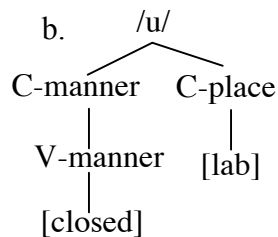
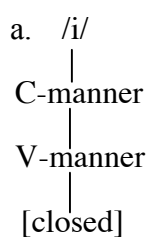
(8) Fricative segments



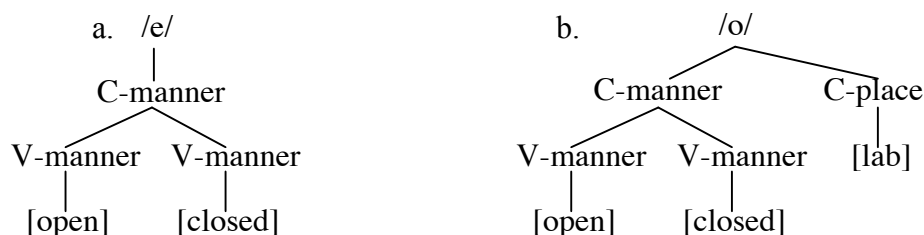
(9) Nasal segments



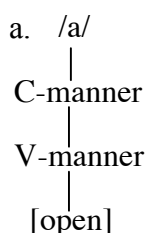
(10) High segments



(11) Mid segments



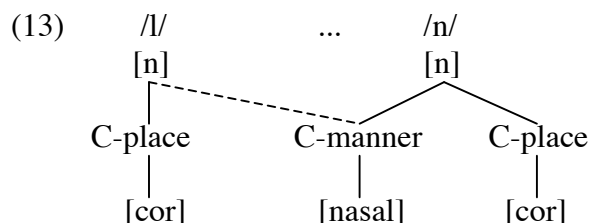
(12) Low segments



Given these phonological representations, the phonetic variation in the realization of [w]/[v] and [l]/[r] is explained by their lack of manner features. Because they are unspecified for phonological closure, they may vary in their closure realization either by phonetic context or freely. Similarly, the phonetic place variation of the mid front vowel that is conditioned by proximity of a phonetically alveolar consonant (i.e. [l, n]) is explained by its lack of a phonologically unspecified place feature - thus it is susceptible to coarticulation effects.¹

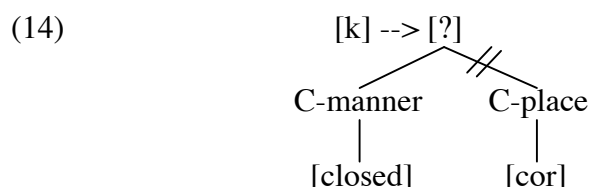
This analysis provides a reason for both the conspicuous absence of contrastive dental/alveolar/palatal obstruents and the free variation that is seen between velar stops and alveolar stops in some dialects. Since there are no sub-place distinctions among consonants using the tongue as an active articulator, then a simple raising of the tongue body to form an obstruent constriction does not have to be specified with respect to the part of the tongue making the constriction. Thus, the tongue root makes as good a “coronal” consonant as the tongue blade would.

We also have a possible explanation for the fact that laterals in some dialects tend to assimilate to coronal nasals within the same word. There may be an acquisition stage in which the nasal feature spreads from a coronal nasal to a mannerless coronal. However, this is not a regular process in the language and only occurs on a word-by-word basis, so the spreading must be “unlearned” at some stage of development and the lexicon restructured.

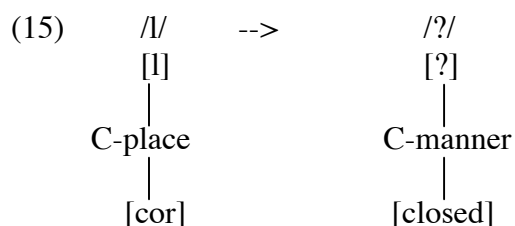


¹ While phonetic variation CAN indicate of a lack of feature specification along a particular phonological dimension, the lack of feature specification NEED NOT imply phonetic variation along that dimension. The relationship between phonetic variability and phonological feature underspecification is asymmetrical.

The lexical alternations between the glottal stop and the velar stop can also be viewed as a relationship between two segments that differ in only the C-place[cor] feature. If the glottal stop is the structurally least complex stop in that it has no place feature, then one might expect neutralizations toward it during acquisition. Again, since this is not a regular phonological process, but a lexical diffusion phenomenon, a point must come in development in which the combination of a manner and place feature is allowed and the lexicon is partially restructured. Viewed as a diachronic change, the neutralization is representationally depicted in (14).



Similarly, the preference for onsets to be actual consonants (defined by C-manner features) to satisfy the sonority sequencing principle (?) might lead forms containing a “defective” onset to surface with the best, yet minimal, consonant. Thus, words with [l] are sometimes lexicalized with glottal stops instead, as shown in (15).



Among vowels, restrictions on the types of diphthongs allowed (i.e. the first element must be more sonorous than the second element) suggest that there are three phonological heights in Hawaiian. This was shown in (4), where relative vowel height/sonority is defined by V-manner features. So, the following three types of diphthongs are licit:

- (16)
- | | |
|--------------------------------------|---|
| a. mid-high - [ei], [eu], [oi], [ou] | V-manner[open, closed] V-manner[closed] |
| b. low-high - [ai], [au] | V-manner[open] V-manner[closed] |
| c. low-mid - [ae], [ao] | V-manner[open] V-manner[open, closed] |

6. Summary

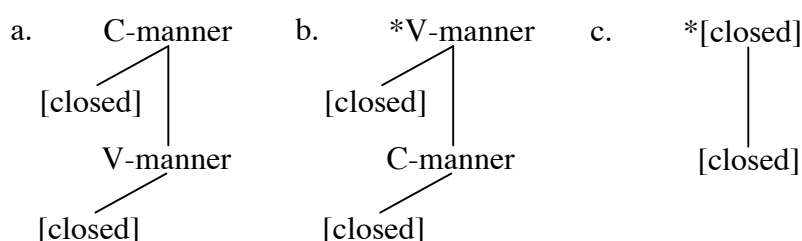
The privative, articulator-based features and restrictions on the assumption of segment-internal complexity of the Parallel Structures Model lead to a simple account of the phonetic and phonological behavior of the Hawaiian segments. Although the relationship between phonological feature specification and phonetic realization in this analysis seems, at first glance, somewhat opaque since one cannot merely read the phonological features off of the static phonetic descriptions (e.g. [k] is phonologically coronal), the actual behavior of the segments (both phonetic and phonological) makes that relationship quite straightforward. In fact, the puzzle of the lack of contrastive dental/alveolar/palatal obstruents combined with the phonological/lexical relationships among [ʔ, k, l and n] are very difficult to explain using theories in which phonological representations are universally mapped to particular phonetic implementations.

7. An OT analysis of the Hawaiian segment inventory (much from Morén (in press))

Most OT analyses in the literature do not explicitly state the mechanism by which the segment inventories of languages are captured using constraints. Nor do they motivate the feature specifications that they assume for given segments. Rather, they simply assume a particular (usually fully-specified) feature set for given segments and use constraint interaction to account for specific phenomena without questioning the validity of those features and constraints for the rest of the language. While such analyses are certainly interesting and address particular theoretical and empirical questions, it is also important to put analyses within the larger context of the grammar of that language. For this reason, I will provide an OT characterization of both the segment inventory and the phonological processes that are the focus of this paper. As we will see, the constraints used to define the segment inventory also play an important role in accounting for other phonological phenomena.

Before providing an OT analysis of Hawaiian, it is important to state some assumptions regarding features, segment-internal representations and featural markedness and faithfulness constraints. First, I assume the Parallel Structures Model features discussed above. Second, I assume that only the representations of the Parallel Structures Model are possible segment-internal structures. Therefore, universally illicit structures are impossible outputs of the Gen(erator) function and are thus absent from the candidate set. This is an explicit statement about the nature of Gen and the grammar, in which Gen, not the constraint ranking, ensures that only particular representations are universally available. It reduces the set of re-rankable constraints and limits the typological predictions made by re-rankable constraints. It also reduces the workload of the Eval(uator) function and makes for a more learnable grammar by eliminating the need for learners to reject universally unavailable structures or consider universally untenable constraint rankings during the acquisition process. Finally, this makes an explicit statement about the division of labor between segment-internal representations and constraints. The representations regulate the possible relationships among segment-internal elements while the constraint ranking determines which representations occur in a given context in a specific language. Some examples of possible and impossible structures are given in (17).

(17) Examples of possible and impossible structures



Third, I assume a Correspondence Theory (McCarthy and Prince 1995) version of faithfulness constraints, but one in which features are treated as autosegments, not attributes. Thus, I use MAX(imality) and DEP(endency) constraints rather than IDENT(ity) constraints. Fourth, the feature markedness and faithfulness constraints make reference to both class node and feature specification. Examples are given in (18) and (19) for some simple features.

- (18) a. *C-manner[closed] - the C-manner[closed] configuration is prohibited.
b. *V-manner[closed] - the V-manner[closed] configuration is prohibited.

- (19) a. **MAXC-manner[closed]** - Every C-manner[closed] in the input has a correspondent in the output (do not delete).
 b. **MAXV-manner[closed]** - Every V-manner[closed] in the input has a correspondent in the output (do not delete).
 c. **DEPC-manner[closed]** - Every C-manner[closed] in the output has a correspondent in the input (do not epenthesize).
 d. **DEPV-manner[closed]** - Every V-manner[closed] in the output has a correspondent in the input (do not epenthesize).

Finally, there are a number of possible ways to formalize constraints against feature co-occurrence. For example, one could have constraints against every possible feature combination, as in (20), or one could have the conjunction of individual feature constraints of the type given in (22).

- (20) ***C-manner[closed]V-manner[closed]** - a structure with both C-manner[closed] and V-manner[closed] is prohibited.
- (21) Local Conjunction² (Smolensky 1997) - The local conjunction of C1 and C2 in domain D, C1 & C2, is violated when there is some domain of type D in which both C1 and C2 are violated.
- (22) ***C-manner[closed]&*V-manner[closed]** - the local conjunction of *C-manner[closed] and *V-manner[closed] is violated when both *C-manner[closed] and *V-manner[closed] are violated by the same segment.

For the purposes of this paper, both the complex structure feature co-occurrence constraints, as in (20), and the local conjunction feature co-occurrence constraints, as in (22), are roughly equivalent. However, I will use the conjoined constraints for reasons that are beyond the scope of this paper.

With essential assumptions made, we can move on to the analysis of Hawaiian. Recall from the representational analysis of Hawaiian provided above that this language has seven segments composed of only a single feature - two segments are mannerless and five segments are placeless. Using the standard OT strategy of ranking markedness constraints below faithfulness constraints to yield a contrast, the following constraint rankings yield these first order contrastive segments.

- (23) a. MAXC-place[lab] >> *C-place[lab] /w/
 b. MAXC-place[cor] >> *C-place[cor] /l/
 d. MAXC-manner[closed] >> *C-manner[closed] /?/
 e. MAXC-manner[open] >> *C-manner[open] /h/
 f. MAXC-manner[nasal] >> *C-manner[nasal] /m/
 g. MAXV-manner[closed] >> *V-manner[closed] /i/
 h. MAXV-manner[open] >> *V-manner[open] /a/

² Local conjunction is an operation by which constraints applying to a specific domain (the segment in this case) are combined such that the conjoined constraint is violated if and only if all its members are violated.

The tableaux in (24) and (25) demonstrate how this provides the correct results for the fricative and the high front vowel. In both tableaux, the feature deletion in candidate (b) is ruled out by the higher-ranked faithfulness constraint.

(24)

/C-manner[open]/		/h/	MAX C-manner[open]	*C-manner[open]
-->	a.	C-manner[open]	[h]	*
	b.	---	[]	*!

(25)

/V-manner[closed]/			/i/	MAX V-manner[closed]	*V-manner[closed]
-->	a.	V-manner[closed]	[i]		*
	b.	---	[]	*!	

In contrast, segments composed of only the features not used in this language (e.g. C-place[dor]) are prohibited because the relevant markedness constraint outranks the related faithfulness constraint, as shown in (26). This means that the dorsal C-place never surfaces in this language.

(26)

/C-place[dor]/	*C-place[dor]	MAXC-place[dor]
a. C-place[dor]	*!	
--> b. ---		*

If we assume that more complex structures are necessarily built up of less complex structures, then the only combinations of features allowed in this language are those making use of the seven features in (4). Combining two of the relevant markedness constraints at a time, we get $7C2 = 7!/(2!(7-2)!) = 21$ second order constraints. This entails 21 logically possible segments composed of two features. Of these, only five are actually used in this language. The allowable combinations of two features are the result of the constraint rankings in (27). Tableau (28) demonstrates how the labial stop results from the ranking in (27b). In contrast, tableaux (29) and (30) show how a labial fricative is not allowed even though both the labial feature and the fricative feature are allowed independently (see (23)).

- (27)
- | | | |
|----|---|-----|
| a. | MAXC-place[lab], MAXC-manner[closed] >> | |
| | *C-place[lab]&*C-manner[closed] | /p/ |
| b. | MAXC-place[cor], MAXC-manner[closed] >> | |
| | *C-place[cor]&*C-manner[closed] | /k/ |
| c. | MAXC-place[cor], MAXC-manner[nasal] >> | |
| | *C-place[cor]&*C-manner[nasal] | /n/ |
| d. | MAXC-place[lab], MAXV-manner[closed] >> | |
| | *C-place[lab]&*V-manner[closed] | /u/ |
| e. | MAXV-manner[closed], MAXV-manner[open] >> | |
| | *V-manner[closed]&*V-manner[open] | /e/ |

(28)

/C-place[lab] C-manner[closed]/	/p/	MAX C-place [lab]	MAX C-manner [closed]	*C-place [lab]& *C-manner [closed]	*C-place [lab]	*C-manner [closed]
--> a.	C-place[lab] C-manner[closed] [p]			*	*	*
b.	C-place[lab] [w]		*!		*	
c.	C-manner[closed] [ʔ]	*!				*
d.	---	[]	*!	*!		

(29)

/C-place[lab] C-manner[open]/		*C-place[lab]& *C-manner[open]	MAX C-place[lab]	*C-place[lab]
a.	C-place[lab] C-manner[open]	*!		*
--> b.	C-place[lab] [w]			*
c.	C-manner[open] [h]		*!	
d.	---	[]	*!	

(30)

/C-place[lab] C-manner[open]/		*C-place[lab]& *C-manner[open]	MAX C-manner[open]	*C-manner[open]
a.	C-place[lab] C-manner[open]	*!		*
b.	C-place[lab] [w]		*!	
--> c.	C-manner[open] [h]			*
d.	---	[]	*!	

Note that there is no evidence with which to decide the relative ranking of either the two faithfulness constraints, MAXC-place[lab] and MAXC-manner[open], or the two markedness constraints, *C-place[lab] and *C-manner[open]. Therefore, a single input containing both features, C-place[lab]C-manner[open], could result in either [w] or [h].³

Combining three markedness constraints at a time using local conjunction, we get $7C3 = 7!/3!(7-3)! = 5040/6(24) = 5040/144 = 35$ third order constraints.⁴ Of these, only one is used in this language.

³ Evidence from borrowing shows that [f] is borrowed into Hawaiian as [p], not [h], thus indicating that C-place[lab] takes preference over C-manner[open]. However, sonority-based syllable preferences (or phonetic cues of obstruentness) leads to the addition of a C-manner[closed] feature, so that [p] surfaces instead of [w]. Although, there is no evidence that foreign [f] is phonologically interpreted by Hawaiian speakers as /C-place[lab]C-manner[open]/.

⁴ Alternatively, third order constraints could be built of combinations of first and second order constraints. This means there is a potential for $21(5) = 105$ third order constraints. However, we get only $5(5) = 25$ possible third order constraints in Hawaiian using the restricted set of second order constraints. Among these, only one is actually used in this language. For our present purposes, the way in which third order constraints are composed (either of combinations of three separate first order constraints or of second order and first order constraints) is unimportant. More work is needed in this area.

(31) MAXV-manner[closed], MAXV-manner[open], MAXC-place[lab] >>
 *V-manner[closed]&*V-manner[open]&*C-place[lab] /o/

(32)

/V-manner[closed] V-manner[open] C-place[lab]/	/o/	MAX V-manner [closed]	MAX V- manner [open]	MAX C-place [lab]	*V-manner[closed]& *V-manner[open]& *C-place[lab]
--> a. V-manner[closed] V-manner[open] C-place[lab]	[o]				*
b. V-manner[closed] V-manner[open]	[e]			*!	
c. V-manner[open] C-place[lab]		*!			
d. V-manner[closed] C-place[lab]	[u]		*!		

There are no violations of the fourth order constraints composed of the seven constraints under investigation in this study. Therefore, corresponding representations do not surface.

To summarize, the constraint ranking necessary to account for the segment inventory of Hawaiian is given in (33).

(33) Hawaiian segment inventory ranking

Unviolated feature markedness constraints	{	all $n^{th} > 3^{rd}$ order markedness constraints, all unviolated third order markedness constraints, all unviolated second order markedness constraints, all unviolated first order markedness constraints
Faithfulness constraints against feature deletion		>> MAXC-place[lab], MAXC-place[cor], MAXC-manner[nasal], MAXC-manner[closed], MAXC-manner[open], MAXV-manner[closed], MAXV-manner[open]
Violated 3 rd order feature markedness constraints		>> *V-manner[closed]&*V-manner[open]&*C-place[lab], *C-place[lab]&*C-manner[closed], *C-place[cor]&*C-manner[closed], *C-place[cor]&*C-manner[nasal], *C-place[lab]&*V-manner[closed], *V-manner[closed]&*V-manner[open], *C-place[lab], *C-place[cor], *C-manner[nasal], *C-manner[closed], *C-manner[open], *V-manner[closed], *V-manner[open]
Violated 2 nd order feature markedness constraints		
Violated 1 st order feature markedness constraints	{	

8. Conclusions

This squib explores the phonetic and phonological sound patterns of Hawaiian, proposes an economical set of feature specifications for the individual segments, and provides a constraint-based account of the inventory facts.

All in all, we see that the simplicity of the phonological grammar of Hawaiian makes it perfect for testing hypotheses regarding phonological features, segment-internal economy, phonetic and phonological dispersion and the mapping between abstract phonological features and their phonetic realizations. The data suggest that both vowel and consonant inventories are subject to phonetic dispersion in that they tend to be as phonetically different⁵ from one another as possible. However, that dispersion is subject to restrictions imposed by an economical phonological grammar and the need to straightforwardly map between phonological features and articulatory gestures. This results in less than obvious links between those features and acoustic cues in models that assume a direct and universal relationship between phonetic “features” and phonological features. However, the Parallel Structures Model, which assumes a less direct, non-universal, but principled relationship, can account for the sound patterns of Hawaiian quite easily.

⁵ Note that in the case of the stops, Hawaiian does not seem to make use of perceptual dispersion since the perceptual (and some phonological) literature suggests that labial and velar stops are perceptually less distinct than labial and alveolar stops. This often leads to diachronic alternations between labials and velars, but not labials and alveolars, and has led some to propose an acoustic feature [grave].