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Rhyme phonotactics in Taiwanese: A dispersion-theoretic perspective*

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This paper argues against a (standard) markedness-based approach to rhyme phonotactics in Taiwanese since analyses in this vein overgenerate by predicting unattested VC gaps. Instead, I explain VC gaps in the following terms. The key point is that the salient places cues of release to a coda stop are absent in Taiwanese (and many other (South) East Asian languages), leaving VC transitions as the only cues and consequently impeding an accurate and reliable identification of place distinctions in coda position. As such place contrasts may be neutralized (henceforth the gaps) because there are systematic asymmetries after particular vowels in terms of their ability to signal place in the upcoming stop. Otherwise, enhancement is invoked to maintain place contrasts, resulting in vowel quality change or emergence of an excrescent schwa (confirmed by an acoustic study reported in this work). I shall show that both "repair strategies" are attested in Taiwanese and Cantonese (and perhaps Hakka) and can be captured by Steriade's (1999) Licensing-by-Cue hypothesis, in tandem with Flemming's (2002) Dispersion Theory of contrast.

1. Introduction

In Sinitic languages, the gaps in the inventory of possible rimes (rhyme phonotactics) have been customarily attributed to some Morpheme Structure Constraint or OT markedness constraint. For example, no two [labial] segments are allowed within a rime, thus excluding ill-formed rimes such as *-*um* or *-*up* in certain Sinitic languages (e.g. Ang 1996, Chung 1996 for Taiwanese and Yip 1998 for Cantonese, among many others). This work challenges this now-conventional approach by pointing out that analyses along this line overgenerates by predicting unattested gaps. For example, why don't we never see effects of, say, OCP([-bk]), eliminating rimes like -*in*? So it is fair to say that a satisfactory (standard) markedness-based account cannot be easily obtained (see section 4 for more discussion). I argue that Flemming's (2002) Dispersion Theory of contrast (or

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Padegtt's (2003) systemic faithfulness and markedness; cf. Liljencrants and Lindblom (1972)) offer a more viable solution to the issues in question. I shall show that the main "trigger" is that vowels may be in danger of perceptual confusion in phonetically shorter syllables (Flemming 2005, Lindblom's (1963) undershoot model) and then perceptual confusion may lead to contextual neutralization, given that sufficient contrasts cannot be maintained due to articulatory difficulties. Hence the gaps are motivated. Moreover, it is also confirmed in my acoustic data that Keyser and Stevens's (2006) enhancement effects may be invoked to avoid potential perceptual confusion. So our results are yet another example confirming the hypothesis that phonologies of languages are determined by phonetic principles (Hayes et al. 2004) because rhyme phonotactics, an unambiguously phonological phenomenon, is motivated by language-specific implementation of phonetic details in a non-trivial way. Finally, from a cross-linguistic perspective, the present analysis can also be extended to rhyme phonotactics in Cantonese and (Meixian and Taiwanese) Hakka.

This paper is organized as follows. In section 2, background and some preliminary data are presented, together with discussion of why the issues in question cannot be appropriately regarded as accidental gaps. Section 3 is an acoustic study of the vowels in Taiwanese under various contexts and then a Dispersion-theoretic analysis is provided, based on the obtained phonetic data. In section 4, I will demonstrate why a markedness-based analysis overgenerates by predicting unattested patterns. Finally, this paper is closed with discussion of VC gaps in Cantonese and Hakka.

2. The gaps

2.1. Statement of the problem

The core data of this study are illustrated in (1) below.

(1) The gaps in the inventory of possible rimes in (Mainstream) Taiwanese

	-p/-m	-t/-n	-k/-ŋ
i	√	√	√
u	×	√	×
ɔ	?	×	√
a	√	√	√

(where √ = attested, ? = rare, ×= unattested)

Like many other Sinitic languages, the maximal Taiwanese syllable has four underlying elements CGVX (e.g. Duanmu 2000), where, modulo the issue of phonemicization, C={p, t, k, p^h, t^h, k^h, b, g, s, ts, ts^h, l, m, n, ŋ, ʔ}, G={j, w}, X={m, n, ŋ, p, t, k, ʔ}. In Mainstream Taiwanese, there are six (6) phonemic oral vowels, {i, e, a, u, o/ɤ̹ (a slightly rounded mid back vowel, mostly found in Southern Taiwan), ɔ} and five (5) nasal vowels, {ĩ, ẽ, ã, (ɔ̃), (ĩũ)} (where /ɔ̃/ is extremely rare and /ũ/ cannot stand alone; also, nasal vowels are not compatible with a coda). Notice further that vowel /o/ is neutralized with vowel /ɔ/ in closed syllables and vowel /e/ is not possible in closed syllables.[1]

Standard markedness constraints alone cannot account for the above gaps; however the constraints are formulated, e.g. the OCP (McCarthy 1986, Yip 1988 among others) or AGREE (Lombardi 1999, among others). Some discussion is in order. Firstly, labial dissimilation works only for *-up* and *-um* rimes, whereas rimes like *-ɔp* and *-ɔm* are not absolutely impossible. In some sub-varieties (mainly Changzhou-accented ones), ginseng is pronounced [sɔm^1] and there are a handful of onomatopoetic expressions such as [hɔp^8] 'to snap' or [tɔp^8] 'water dripping sound'. There is no denying that forms like these are very rare but they do exist, suggesting that these rimes are disfavored by some other independent reason, rather than featural co-occurrence restrictions. Secondly, and more importantly, it is quite questionable as to why there are neither coronal dissimilation nor velar dissimilation, if any. For instance, suppose that front vowels are coronal (Hume 1994; cf. Flemming 2003) and then it is puzzling why rimes like *-in* or *-it never* seem to be subject to dissimilation, to the best of my knowledge. I will argue extensively in section 4 that various rankings of standard markedness constraints are of no avail in this regard, because, as mentioned at the outset, overprediction is doomed given a standard markedness-based account. Finally, there are still other gaps that may have nothing to do with co-occurrence restrictions. For example, it is likely that **-uk* and **-uŋ* are ruled out by the constraint OCP-([+high]) (following Sagey's (1990) model), but what about *-ik* or *-iŋ* (see also fn. 1)? Also, since *-un* and *-ut* are perfectly fine, there is no apparent reason why **-ɔt* and **-ɔn* are not attested because vowels /ɔ/ and /u/ differ mainly in F1 (and perhaps in tenseness and rounding, which are obviously not so relevant here). We have learned from (1) that vowel height is not subject to dissimilation in Taiwanese (e.g. *-ik/-iŋ*). In sum, as a first approximation, it is fair to say that featural co-occurrence restrictions seem to fail to provide a satisfactory, unified account for the VC gaps in Taiwanese.

2.2. The spotty data problem

Before we move on to the analysis, it is necessary to discuss a non-trivial issue firstly noted in Duanmu (2008), i.e. "there are often not enough data for making reliable generalizations, even if we examine the entire lexicon of language." The gist of Duanmu's concern, or the spotty data problem, is that we may never know if an unattested structure is ruled out (or not generated) by grammar or is simply an accidental gap. Indeed, this quandary is not a trivial one and is relevant to the issues in question. To see why this problem is not at issue here, a comparison table in (2) may be of help, while

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[1] Vowel /e/ is, diachronically speaking, a "derived" vowel, resulting from the coalescence of /ai/ at some point. Also, in Church Romanization (or, POJ, which was firstly invented in Amoy/ Xiamen, China), rimes like *-ik* or *-iŋ* are spelled ek and eng. Those spelling forms do not correspond to the actual pronunciation in Mainstream Taiwanese. Incidentally, vowel /i/ is lowered in the current context in some other varieties of Southern Min, for example, Chaozhou.

in the future it is definitely needed to test for the acceptability of the (non-)gaps by means of a series of psycholinguistic experiments. Recall from (1) that vowel /u/ does not co-occur with a velar coda in Taiwanese. Is it possible to posit that a high back vowel must be lowered in closed syllables in Taiwanese? The answer is negative because that is not true if we look at the second Taiwanese example in (2), whereby vowel /u/ is attested in a closed syllable as long as the coda is coronal, i.e. [sut^8] 'skill, art'. More importantly, as we can see in (2), the word 'poison' in Hakka and Cantonese is undoubtedly a cognate of Taiwanese but vowel /u/ is perfectly fine in closed syllables in these two closely related languages, suggesting that it may not be appropriate to treat *-uk* or other gaps as mere accidental gaps. Thus, I conclude that at least the VC gaps in (1) are grammatically conditioned, but not an accidental gap.

(2) A (over-simplified) cross-linguistic comparison

Taiwanese	Hakka	Cantonese	Gloss
tɔk (*-uk)	t^huk	tuk	'poison'
sut (*-ɔt)	sut	sœt	'skill, art'

3. Towards a dispersion-theoretic account

We have assumed previously that VC gaps are not markedness-driven. The aims of this section are to pinpoint the motive force behind the observed patterns of rhyme phonotactics and then to provide a Dispersion-theoretic account for the phenomena in question. In light of Steriade's (1999) Licensing-by-Cue hypothesis and the subsequent P-map hypothesis (Steriade 2009), we need to explore why stop codas in Taiwanese are so confusable that a "grammatical response" is inevitably invoked. Regarding perceptual confusability, the basic claim is that there are two possible "repairs" in grammar. Enhancement effects, on the one hand, refer to the mechanism that different allophones are assigned along some acoustic dimension in order to enhance a phonemic contrast (Keysers and Stevens 2006). Contextual neutralization, on the other hand, may occur when a contrast cannot be reliably maintained. As we will see below, both are attested in the phonology of VC gaps in Taiwanese (but see Flemming 2006).

3.1. Triggers

The contextual confusability in question is mainly due to the fact that stop codas are never released, even in extremely careful speech in Taiwanese (and in most (South) East Asian languages).[2] So this language-particular implementation of stop codas impedes proper identification of places of articulation (see Chu et al. 2008 for a proposal along this line). Importantly, it has been confirmed that release bursts are the most salient cue

[2] Another distinct trait is that stop codas are normally reinforced by different degrees of "glottalization" (see Edmondson et al. 2010 for recent laryngoscopic studies of Taiwanese and Vietnamese and references cited therein).

for stop place (Stevens and Blumstein 1978, Blumstein and Stevens 1979, Stevens 1994, among others). Among other cues, formant transitions are not reliable, even in CV (Delattre et al. 1955), while F2 Loci (Stevens and Houses 1956, 1966) or Locus equations (LEs, Sussman et al. 1991, Sussman 1994, among others) are also not sufficient to serve as the specifier of places (e.g. Fowler 1994). Our claim is further supported by the fact that, as far as I know of, languages with released stop codas do not have (systematic) VC gaps. Furthermore, it is important to note that, in such languages, phonotactic restrictions occur exactly in environment where release bursts may be vulnerable or even absent, e.g. stop-stop clusters in English (see, for example, Wright (2001) for more discussion).

Closed syllable laxing, on the other hand, serves as the other motive force behind the phenomena in question. Lindblom (1963) proposes that vowel space contracts (i.e. centralization) as vowel duration is reduced, resulting in undershoot in short unstressed syllables, provided that effort minimization is at play. Vowel contrasts are subject to merger when it is difficult to maintain a distinction where vowel duration is shorter and insufficient contrasts emerge as a function of centralization (Flemming 2005). Taken together, in order for the present analysis to work, it is necessary to see if the above-mentioned phonetic properties are indeed attested in Taiwanese. So I present results of an acoustic study of the vowels in Taiwanese in different contexts, to which I shall return in the following section.

3.2. Phonetic underpinnings: An acoustic study

Ten male speakers participated in this study. They are all native speakers of Taiwanese. Seven speakers are in their 20s and three speakers in their 60s. All participants were born and raised in Taiwan (five from Northern Taiwan and five from Southern Taiwan) and never left Taiwan for more than half a year. They were paid for their participation in this experiment. In this paper, I reported the data from two younger male speakers from Southern Taiwan.

The test material used in this study consisted of 299 monosyllables. The target words are all controlled for the following syllable types: CV, CVN and CVS, where C={unaspirated voiceless stops: p, t, k; if not available, voiceless fricatives or affricates: s, h, ts}, V={ i, e, a, u, ɤ̹[3], ɔ for open syllables; i, a, u, ɔ for closed syllables}, N={m, n, ŋ}, and S={p, t, k}. CV and CVN syllables were produced with a high level tone (Tone 1/*Yinping*) and a high falling tone (Tone 2/*Yinshang*) was used, if Tone 1 is not available. CVS syllables are only compatible with checked tones, namely, Checked Mid (Tone 4/*Yinqu*) and Checked High (Tone 8/*Yangqu*). All target words were produced in this carrier phrase: "*tsit-e li si* __. 'this word is __'". Each sentence was repeated three times, yielding a total number of 897 tokens.

[3] Note again that this slightly rounded mid back vowel /ɤ̹/ corresponds to vowel /o/ in the variety spoken in Northern Taiwan. In this paper, I reported the data from the variety spoken in Southern Taiwan, especially Tainan, Kaohsiung and Pingtung.

Recordings for acoustic analysis were taken in a soundproof room at the NTHU phonetics lab with a digital recorder (Roland Edirol R09) and a high-quality microphone (Beyerdynamic TGX480) with sampling rate of 44.1 kHz. All speakers were literate and accustomed to reading Chinese characters in Taiwanese. They were asked to read randomized sentences of Taiwanese from a computer screen.

The acoustic analysis procedure was similar to that used in Zee (2000), using Praat (Boersma and Weenink 2010). The formant values were extracted from the start, mid, and end points with the help of a Praat script developed at the NTHU Phonetics Lab. The obtained formant values were subsequently normalized by means of the Lobanovian method, using a web-based software package of vowel normalization, NORM (Thomas and Kendall 2007). Consider now the vowel plots below. Recall that vowels /e/ and /ɤ̞/ are not possible in closed syllables. The data are from two young male speakers from Southern Taiwan.

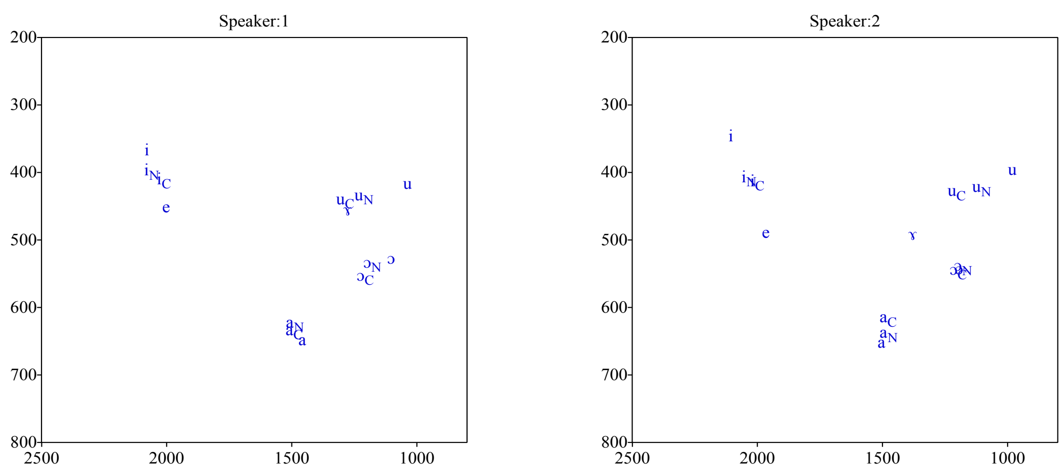

Figure 1. Lobanov normalized vowels of Taiwanese (mean values for midpoint; where $_N$= vowels with a nasal coda; $_C$= vowels with a stop coda)

From Figure 1, it is obvious that vowels are centralized in closed syllables, while vowels in checked syllables are most centralized. There was a significant difference in mean F1 and F2 values for the vowels in open syllables and for the vowels in closes syllables: all are significant at the 0.05 level, except Speaker 2's vowel /ɔ/. The results thus suggest that the space of Taiwanese vowels contracts significantly in checked syllables. Next, the data of vowel length in open syllables and closed syllables are reported in (3). As we can see, vowel duration is significantly reduced in checked syllables; vowels in open syllables are (at least) twice longer than vowels in checked syllables (i.e. in a ratio of 2:1).

(3) Vowel duration (in ms; SD in parentheses)

	CV	CVC
Speaker 1	267.8 (66.8)	75.0 (18.8)
Speaker 2	219.9 (43.1)	104.7 (15.6)

In sum, the present results confirm that vowel centralization and length reduction are both attested in checked syllables in Taiwanese, even though the test words were embedded in sentence-final position, one of the prosodically prominent positions that is cross-linguistically most subject to lengthening effects (e.g. Hsieh 2005). All in all, it is safe to say that vowels are more confusable with one another in the above contexts, thus motivating grammatical responses to avoid the low perceptibility of (post-)vocalic place distinctions.

3.3. The repairs: a view from formant movement

There are two logically possible repairs for confusable contrasts, namely, contextual neutralization (i.e. loss of contrasts) or enhancement (i.e. to keep contrasts sufficiently distinct by "enlarging" acoustic differences). In the Taiwanese data, we see both are used to avoid the low perceptibility of (post-)vocalic place distinctions. Interestingly enough, nonlow, back vowels opt for neutralization, as vowels /u/ and /ɔ/ are in complementary distribution when in closed syllables (see (4)). One may wonder why we should care about non-existing rimes such as **-uk* below. As we have discussed in section 2.2, these non-occurring forms cannot be accidental gaps if cognates of related languages are taken into consideration (and perhaps given the Richness of the Base Hypothesis (ROTB, Prince and Smolensky (2004)). Consequently, these gaps are better regarded as an ill-formed structure.

(4) Neutralization in nonlow, back vowels in closed syllables

Potential contrasts	Surviving forms
-uk vs. -ɔk	[ɔk]
-ut vs. -ɔt	[ut]
-up vs. -ɔp	[ɔp] (rare but attested)

By contrast, to avoid potential confusion, front and low vowels (/i/ and /a/) have recourse to vowel quality change or diphthongization (or, an excrescent schwa). It is important to note that these vowels do not have "neighbors" (e.g. /e/ or /æ/, respectively) in closed syllables (as a result of diachronic changes; fn. 1). Therefore, no contextual neutralization is expected. On the other hand, at first blush, one may wonder why a three-way contrast is possible in (5). The reason is straightforward: for front vowels, only vowel /i/ is attested in closed syllable and there is only one low vowel /a/ in Taiwanese. In other words, the present observation lends further support to this important generalization: neutralization does not occur in absence of contrasts (e.g. Flemming 2002). We do not expect gaps under these circumstances simply because, again, there are no other contrasting forms, e.g. *-*ek* or *-*en* (see also fn. 1). Consequently, enhancement is motivated to avoid potentially confusable forms. As we can see in (5), an excrescent schwa shows up when high front vowel /i/ precedes a velar coda. The low vowel /a/ is (slightly) fronted or backed when followed by a coronal or velar coda, respectively. This is reminiscent of “rime harmony” in Mandarin Chinese, whereby a front vs. back low vowel is required to co-occur with a dental vs. velar nasal coda, respectively (Duanmu 2000, Hsieh et al. 2009; see Flemming 2003 for the phonetic basis of such a constraint).

(5) Enhancement in front and low vowels in closed syllables

Contrasts	Surviving forms	Remarks
-ik vs. -ip vs. -it	[iᵊk], [ip], [it]	Excrescent schwa
-at vs. -ak vs. -ap	[a̙t], [a̘k], [a̘p]	Vowel quality change, “rime harmony”

Formant movement patterns of Taiwanese vowels in checked syllables are illustrated in Figure 2. Notice that, for typographic reasons, /oo/ stands for /ɔ/ below. The data are from the same two younger speakers from Southern Taiwan.

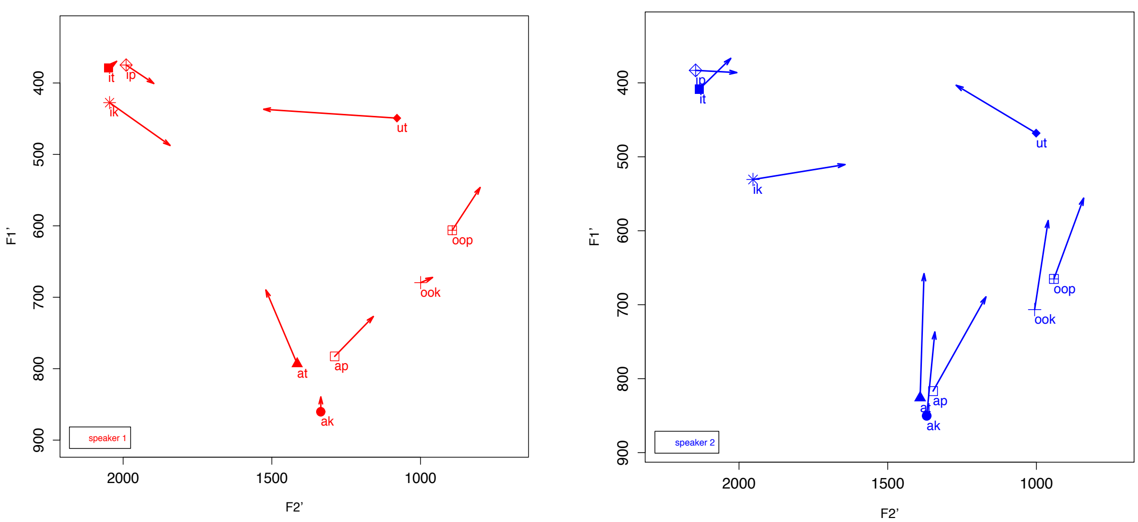

Figure 2. Formant movement patterns of Taiwanese vowels in checked syllables (from midpoint to offset, marked with an arrow. Note that /oo/ stand for /ɔ/.)

We observe from Figure 2 that, coda /-p/ compresses F2; coda /-t/ raises F2; coda /-k/ lowers F2, towards the endpoints. As we can see, the VC transition patterns of the two speakers are largely collaborative and also conform to the descriptions in (4) and (5). The present patterns to a great extent confirm the well-established acoustic loci for consonants, and, more importantly, indicate that faithfulness to the consonantal places is prioritized considerably high because there is good evidence that FAITH-(V) outranks

FAITH-(C) in Taiwanese, for example, palatalization: /tsi/ → [tɕi] (e.g. Ang 1996, Chung 1996).

It is important to note that nonlow, back vowels resist enhancement because one of the major articulators of back vowels is Tongue Dorsum (TD). Faster movements are not easily executable with less mobile TD, deterring vowel quality change as a possible solution to enhance a phonemic contrast. Furthermore, it is well-known that centralized vowels do not tend to be rounded, cross-linguistically speaking. On the other hand, front vowels involve TD to a less extent, thus facilitating a shift of horizontal tongue position. Also, low vowel /a/ is more prone to contextual variations along the F2 dimension in absence of contrasting forms. In sum, it may well be the case that the choices are determined by functional factors such as physiological limitations and avoidance of neutralization.

3.4. More on neutralization

More remarks must be made with regard to neutralization of nonlow, back vowels in closed syllables. The relevant data are illustrated again in (6) below.

(6) Neutralization in nonlow, back vowels in closed syllables *redux*

Potential contrasts	Surviving forms	Remarks
-ut vs. -ɔt	[-ut]	[-ut] is closer to the locus of [t]
-up vs. -ɔp	[-ɔp]	Both are equidistant to the locus of [k]; [-ɔp] is less deviant from the input /ɔ/
-uk vs. -ɔk	[-ɔk]	Both are equidistant to the locus of [k]; [-ɔk] is less deviant from the input /ɔ/

Along the F2 dimension, we expect that *-ut* is favored if faithfulness to vowel "is high enough", because less formant movements are involved from the midpoint of /u/ to /t/. In other words, this preference comes from the assumption that phonetic realization of vowel /u/ will be less deviant when combined with /t/, if compared with the (hypothetical) vowel in **-ɔt* rimes, according to Steriade's (2009) P-map hypothesis. On the other hand, although both /u/ and /ɔ/ are more or less equidistant to the loci of /p/ and /k/, vowel /ɔ/ fares better here in terms of the P-map Hypothesis, because, again, less formant transitions are needed, due to the fact that /ɔ/ are more centralized than /u/ (see Figures 1 and 2). In sum, the basic claim here is that the target of neutralization is determined by whether or not a potential phonetic realization is faithfully rendered and thus is more faithful to the input. Alternatively, the present patterns of neutralization can be interpreted as results of minimization of articulatory efforts. But I won't go any further here because of the lack of kinematic data.

Due to space limits, it is not possible to provide a comprehensive analysis of the phenomena in question, but the above guiding ideas will be sufficient, if couched with

Flemming's (2002) Dispersion Theory of contrast as well as Flemming's (2001) weight constraint-based constraints.

4. Is rhyme phonotactics markedness-driven?

I have mentioned at the outset that rhyme phonotactics cannot be solely attributed to standard markedness effects. Analyses along this line normally have the following characteristics. First, the ill-formedness of a given sequence is due to the OCP violation or something like AGREE. Second, the "application domain" for a proposed constraint is basically defined within a rime. I will focus on the first problem below, by pointing out that the existence of subsyllabic constituents has been questioned, e.g. in Yip (2003) and it was reported in a concept formation experiment that rime may not be a phonological unit in Taiwanese (or, Derwing's (2007) Minnan Chinese).

To see why a standard markedness account overpredicts attested patterns, let us first look at a factorial typology in (7). It has been noted that Prince and Smolensky's (2004) use of universally fixed rankings like *Lab, *Dor » *Cor is empirically problematic (see, for example, de Lacy 2006 for an overview). So I assume free rankings of relevant constraints below. Notice further that OCP-$(\text{lab})_{\text{Syllable}}$ may not be active anymore because the English loanwords like *pɐm* 'pump', an obvious violation of the well-established labial dissimilation constraint, do exist (e.g. Bauer and Benedict 1997).

(7) A factorial typology: Co-occurrence restrictions on syllable/morpheme

<u>Rankings</u>	<u>Remarks</u>
OCP-$(\text{lab})_{\text{Syllable}}$ » *M*	Cantonese: **pam*, **pap*, etc.
OCP-$(\text{cor})_{\text{Syllable}}$ » *M*	A language banning: **tan*, **tat*, etc.
OCP-$(\text{dor})_{\text{Syllable}}$ » *M*	A language banning: **kaŋ*, **kak*, etc.

(where *M* = other co-occurrence constraints)

It appears that only effects of OCP-$(\text{lab})_{\text{Syllable}}$ are attested above. To the best of my knowledge, co-occurring coronals or velar sounds (within a syllable) are never subject to the OCP violation, at least in Sinitic language (but note the ill-formedness of **skak* or **spap* in English, for example). Likewise, restricting the application domain to rime does not fare better, either, since similar patterns are again wrongly predicted, as in (8).

(8) A factorial typology: Co-occurrence restrictions on rime

<u>Rankings</u>	<u>Remarks</u>
OCP-$(\text{lab})_{\text{Rime}}$ » *M*	Cantonese: **um*, **op*, etc.
OCP-$(\text{cor})_{\text{Rime}}$ » *M*	A language banning: **in*, **it*, etc.
OCP-$(\text{dor})_{\text{Rime}}$ » *M*	A language banning: **aŋ*, **ak*

(where *M* = other co-occurrence constraints)

Finally, markedness of place of articulation may be reversed (contra de Lacy 2006), as we can see in (9) below. For example, for a two-way contrast, all possible combinations are attested: {p, t}, {t, k} and {k, p}, and it turns out that {k} is the most "unmarked" place in coda position, when it comes to a one-way contrast (excluding the glottal stop for now), at least for checked syllables in Sinitic languages.

(9) Free ranking: A factorial typology (based on Yuan et al. 1983 and references cited therein)

Rankings	Remarks	Languages
*lab » *M*	Codas -t, -k are allowed	Nanchang Chinese
*cor » *M*	Codas -p, -k are allowed	Chaozhou Chinese
*dor » *M*	Codas -p, -t are allowed	Linchuan Chinese[4]
*lab, *cor » *M*	Coda -k is allowed	Fuzhou (old speakers)
*lab, *dor » *M*	Coda -t is allowed	?
*cor, *dor » *M*	Coda -p is allowed	?
*lab, *cor, *dor » *F*	No (stop) coda is allowed	Mandarin Chinese
F » *lab, *cor, *dor	Three-way contrast	Cantonese, Hakka, Taiwanese

(where *F* = faithfulness constraints)

While a comprehensive examination of the present issues is beyond the scope of this work, it is safe to conclude that employing standard markedness constraints alone, either freely rankable with one another or standing in stringency relations, fail to account for the full array of the attested data.

5. Other Sinitic languages

Before we conclude this paper, it is beneficial to see if the proposed analysis is applicable to related languages. This is because, in Sinitic languages, checked syllables are implemented in an identical fashion, as far as I know of. For present purposes, we briefly discuss VC gaps in Cantonese and (Mexian) Hakka. Both have a typical three-way contrast of places of articulations in coda position.

5.1. Cantonese

Cantonese, unlike most Sintic languages, has a three-way distinction of vowel length (Zee 2000 and references cited therein), i.e. long vowels in open syllables, half-long and short vowels in closed syllables. Consider now the results of Zee's (2000) acoustic study, based on mean formant values at the midpoint and the data are from ten male speakers.

[4] According to Tsao and Yeh's (2006) fieldwork, coda /k/ was generally lost/debuccalized in Zhao'an Hakka, keeping a three-way contrast, i.e. /-p/ vs. /-k/ vs. /ʔ/, although coda /k/ is sparsely attested.

(10) A three-way distinction of vowel length in Cantonese (Zee 2000)

Long vowels	{i, y, ɛ, œ, a, ɔ, u}	approx. 350 ms
Half-long vowels	{i, y, ɛ, œ, a, ɔ, u}	approx. 200 ms
Short vowels	{ɪ, ɵ, ɐ, ʊ}	approx. 120 ms

Notices that the short vowel [ɵ] is possible only when flanking segments are coronal (i.e. additive effects in Flemming 2001). As such, it is remarkable that neutralization occurs only when in short syllables (cf. (3)). In other words, vowels may not be confusable enough in long and half-long syllables. It follows that no neutralization is expected in those (phonetically) long syllables. I thus conclude that the Cantonese data do not only support the proposed analysis but also provide a crucial piece of evidence for Lindblom's undershoot model.

5.2. Loose ends: Hakka

The VC gaps in Hakka seem to constitute a real challenge to a Dispersion-theoretic analysis. From a recent study of Meixian Hakka (Lee and Zee 2009), it is evident that nonlow, back vowels remain distinct when in closed syllables, and meanwhile no enhancement effects (e.g. vowel quality change) are reported, as shown in the shaded cells in (11) below. The varieties spoken in Taiwanese, Sixian or Hailu Hakka, also exhibit similar distribution of VC gaps, as far as I know. So far, I have no explanation for the Hakka data, awaiting a closer examination in the future.

(11) Meixian Hakka (based on Lee and Zee 2009)

	-p/-m	-t/-n	-k/-ŋ
i	√	√	×
e	√	√	×
a	√	√	√
ɔ	×	√	√
u	×	√	√
ə	√	√	×

6. Conclusion

With the reintroduction of the systemic view into phonology, we have witnessed a lot of successes in explaining phonological patternings. In addition, another emerging view is that phonologies of natural languages are shaped by phonetic principles. It is hoped in this attempt that one of the most old issues in Chinese phonology, rhyme phonotactics, does lend support to both of the current trends in phonology.

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