The Syllable Phonology of Mandarin and Shanghai*

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Duanmu (2000) noted that most conceivable syllables are missing in Mandarin Chinese and offered an analysis of the missing syllables with two constraints, which were thought to be universal. In this paper I offer a revised analysis in which two universal constraints are proposed, *Rime Harmony* and *Merge*, along with some language specific constraints that are natural but not universal. In addition, I extend the analysis to Shanghai, which has a very different pattern of syllable structure. I show that most missing syllables can be systematically accounted for. The results have implications for the reconstruction of historical phonology, syllable theory in general, and the nature of language universals.

1. Introduction

In traditional descriptions the Chinese syllable is divided into an 'initial' and a 'final'. The initial is usually a consonant. The final consists of a 'medial' and a 'rime', where the medial is a glide before the nuclear vowel and the rime consists of the nuclear vowel and a consonant (ignoring tone). The analysis of the initial is relatively straightforward, but the analysis of the final is controversial. For example, researchers often differ on the transcription of the final, how the final should be decomposed, and how many vowel phonemes there are after the decomposition. In addition, it is unclear why certain finals occur but others do not. To avoid such problems, You et al. (1980) propose that the Chinese syllable should not be decomposed too far. In particular, they propose that the syllable in Standard Chinese (Mandarin) consists of three parts, an 'onset phoneme' (a consonant, which Mandarin has 21), a 'medial phoneme' (a glide, which Mandarin has 3), and a 'rime phoneme' (which Mandarin has 18, not to be further decomposed).

Studies in generative phonology usually divide the Chinese syllable into four elements CGVX, where C is a consonant, G a glide, V a vowel, and X an offglide of a diphthong or a consonant (Cheng 1973, Lin 1989, Duanmu 1990). However, two questions still remain. First, there is some uncertainty with regard to the allophonic values of V, and hence with the rules or constraints that are need to account for them. Second, it remains unclear why many syllable patterns are missing.

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Duanmu (2000) proposes that most missing syllable patterns can be accounted for by two constraints: Rime Harmony and Dissimilation. However, several questions remain (to be reviewed below). In addition, it is unclear whether the analysis can be extended to other Chinese dialects.

In this paper I propose some revisions to Duanmu's (2000) analysis of Mandarin. Then I extend the analysis to the syllable in Shanghai. Finally, I discuss some implications of the analysis.

2. Mandarin

Following other analyses in generative phonology, I assume that the maximal Chinese syllable has four underlying elements CGVX. Duanmu (1990, 2000) also argues that CG merge into one sound at the surface level, but this issue need not concern us here. In many analyses (e.g. Chao 1968, Cheng 1973), Mandarin has 21 initial consonants. In contrast, Duanmu (2000) argues that the three palatals are not underlying phonemes. The list of initial consonants are shown in (1), where the palatals are shown in parentheses.

(1) Initial consonants in Mandarin (excluding the 'zero initial')

p, t, k, p^h, t^h, k^h, ts, ts^h, s, ʈʂ, $ʈʂ^h$, ʂ, f, x, m, n, l, r, (tç, $tç^h$, ç)

For lack of space, I will not discuss the initial consonant further but will focus on the interaction within GVX (see Duanmu 2000 for the interaction within CG). According to Chao (1968), there are 35 GVX forms, shown in (2).

(2) 35 GVX forms (Chao 1968, excluding syllabic consonants)

i	u	y	ɤ
ᴀ	iᴀ	uᴀ	
iɛ	yɛ		
uo			
ai	iai	uai	
ei	uei		
ɑu	iɑu		
ou	iou		
in	yn		
ən	uən		
an	iɛn	uan	yan
ʌŋ	iŋ	uʌŋ	
ɑŋ	iɑŋ	uɑŋ	
ʊŋ	iʊŋ		

It is possible to reduce the GVX forms to five vowels and two nasals (Cheng 1973, Lin 1989, Duanmu 2000). The vowels are shown in (3).

(3) Mandarin vowels

High vowels/glides	i	u	y
Mid vowel	ə		
Low vowels	a		

Now if all sounds are freely combinable under CGVX, there should be many more possible syllables than are actually used. For example, if we assume 18 Cs, 3 Gs, 5 Vs, and 4 Xs (2 glides [i u] and two nasals), there should be 1900 possible syllables (without tones), but the actual number is only about 400. This is shown in (4)

(4) Possible number of syllables: 19C * 4G * 5V * 5X = 1900
Actual number of syllables: 400

In (4), there are 19 choices for C (18 Cs, plus no C), 4 choices for G (3 Gs, plus no G), 5 choices for V, and 5 choices for X (2 Gs, 3 nasals, plus no X), whose product is 1900. However, less than one fourth are found. If we focus on the GVX part alone, the proportion of missing forms is still quite large, as shown in (5).

(5) Possible number of GVX: 4G * 5V * 5X = 100
Actual number of GVX: 35

In (6) I show the complete list of 100 possible GVX forms, in phonetic symbols, where '0' indicates lack of G or X. For clarity, high vowels are written as glides before the nuclear vowel. It is worth noting that Duanmu (2000) included five more rows of GVX—those where X is [y]. Since [y] never occurs in the coda, I have exclude those rows.

(6)

		0-	j-	w-	ɥ-	
[-0]	i	+	(+)	-	-	ji = i
	u	+	-	(+)	-	wu = u
	y	+	-	-	(+)	ɥy = y
	ə	+	+	+	+	
	a	+	+	+	-	
[-n]	in	+	(+)	-	-	jin = in
	un	-	-	-	-	
	yn	+	-	-	(+)	ɥyn = yn
	ən	+	-	+	-	
	an	+	+	+	+	

[-ŋ]	iŋ	-	-	-	-	
	uŋ	+	+	(+)	-	wuŋ = uŋ
	yŋ	-	-	-	-	
	əŋ	+	+	+	-	
	aŋ	+	+	+	-	
[-i]	ii	(+)	(+)	-	-	ii = i, jii = ji
	ui	-	-	-	-	
	yi	-	-	-	-	
	əi	+	-	+	-	
	ai	+	+	+	-	
[-u]	iu	-	-	-	-	
	uu	(+)	-	(+)	-	uu = u, wuu = wu
	yu	-	-	-	-	
	əu	+	+	-	-	
	au	+	+	-	-	

Actual ‘+’:	35
Missing ‘-’ or ‘(+)’:	65
Total:	100

The symbol (+) indicates a form that does not contrast with another. For example, there is no contrast between [ji] and [i]. In such cases, the longer form was marked with (+).

A question we must answer is: Why are so many syllables and GVX forms missing? There are two possible views, shown in (7).

(7) Two views on missing forms
a. The missing forms are due to arbitrary choices of a dialect
b. Most missing forms are due to systematic constraints

According to the first, which syllables are used in a language is arbitrary and accidental, and there is no further explanation. According to the second, the missing forms indicate systematic constraints on possible syllable structures. To support the second view, one should look for two kinds of evidence. First, one should show that there are indeed reasonably natural constraints for most of the missing forms. Second, one should show that the constraints apply to other Chinese dialects (and to other languages), in the sense that most missing forms in Mandarin are also missing in other dialects (and in other languages).

Duanmu (2000) argues that most missing GVX forms in Mandarin can be accounted for by two constraints, shown in (8).

(8) *Rime Harmony*: VX cannot have opposite values in [round] or [back]
Dissimilation: *[ii], *[uu]

Rime Harmony assumes ‘contrastive specification’ of Steriade (1987), instead of ‘radical underspecification’ of Archangeli (1988). It disallows the combination of two sounds AB if they are [+back][-back] or [-back][+back]. In addition, [-back][-back] and [+back][+back] are ruled out by Dissimilation. On the other hand, if A or B is unspecified for [back], then AB can pass both constraints. The same works for the feature [round].

Duanmu (2000) suggests that the constraints have a physiological explanation: an articulator cannot move fast enough to execute two opposite features in succession (such as [+back][-back]), or the same feature twice in succession (such as [-back][-back]). However, there are two problems. First, it is not explained why English allows [ei] (in some dialects), which seems to be [-back][-back]. Second, Dissimilation was allowed to apply across a sound unspecified for [back] or [round]. For example, [iai] was ruled out because [a], being the only low vowel, was unspecified for [back], and so [iai] violates Dissimilation *[ii]. However, if *[ii] was bad because an articulator cannot execute the same gesture twice in succession, it is unclear why it cannot execute [i] again after a rest in [a]. In addition, in some analysis (such as Chao 1968), [iai] is a possible (though somewhat marginal) syllable in Mandarin. Besides, [iai] is used in some dialects. A further problem with Dissimilation is that while two identical features are generally bad cross-linguistically, a long feature is generally good. Therefore, sound pairs like [ii] could become [i:], instead of being ruled out.

In this paper I propose a revised analysis in which Dissimilation is replaced with Merge, shown in (9).

(9) Present analysis

Rime Harmony:	VX cannot have opposite values in [round] or [back] *[a back][-a back], *[a round][-a round]
Merge:	Two tokens of the same feature merge into one long feature [FF] = [F:]

As in Duanmu (2000), I assume that the constraints have a physical explanation, that is, an articulator cannot perform two gestures in a short time. If so, the constraints should be universal for all languages. Besides the constraints in (9), I propose three other constraints, which are natural but probable not universal, shown in (10).

(10)

G-Spread:	A high nuclear vowel spreads to G [i] → [ji], [u] → [wu], [y] → [ɥy]
Triphthong Raising:	[high][mid][high] = [high][high][high] [wəi] = [wi], [jəu] = [ju], [jən] = [jin], etc.
**GY*:	[y] cannot be preceded by a glide *[jy], *[wy]

G-Spread is an anticipatory effect. Triphthong Raising says that, since [high][mid][high] is often raised to [high][high][high], there is no contrast between the two; the effect has been observed in Chinese (Zee 2003) and can be understood in terms of articulatory effort reduction. *GY also seems to be related to articulatory ease, although its precise nature remains somewhat unclear. G-Spread is not universal because in English [ist] 'east' and [jist] 'yeast' are contrastive. Similarly, Triphthong Raising is not universal because English has [wi] 'we' and [wei] 'way' contrastively (in some dialects).

Of the 25 rows in the GVX table, Rhyme Harmony and Merge rule out 9, shown in (11), where [n] is [-back] and [ŋ] is [+back]. Since Mandarin has only one mid vowel and one low vowel, they are unspecified for [back] or [round], and so they can combine with any glide or high vowel.

(11) Rows ruled out by Rhyme Harmony and Merge

*row-[un]	differ in frontness
*row-[iŋ]	differ in frontness
*row-[yŋ]	differ in frontness
*row-[ui]	differ in rounding and frontness
*row-[yu]	differ in frontness
*row-[yi]	differ in rounding
*row-[iu]	differ in rounding and frontness
*row-[ii]	Merge, [ii] = [i:]
*row-[uu]	Merge, [uu] = [u:]

Because all regular Mandarin syllables are heavy, a rime with just [i] or [u] are in fact long [i:] and [u:] (Duanmu 1990, 2000), and so there is no contrast between them and [ii] and [uu] under Merge. Of the remaining 16 rows, G-Spread (G), Triphthong Raising (T), and *GY (Y) reduce 20 additional cells, as shown in (12).

(12)

	0-	j-	w-	ɥ-	
i	+	G	+	-	ji = i
u	+	+	G	-	wu = u
y	+	Y	Y	G	ɥy = y
ə	+	+	+	+	
a	+	+	+	-	
in	+	G	+	-	jiṇ = in
yn	+	Y	Y	G	ɥyn = yn
ən	+	T	T	T	jən = jin, wən = win, ɥən = ɥin
an	+	+	+	+	
uŋ	+	+	G	-	wuŋ = uŋ
əŋ	+	+	+	T	ɥəŋ = ɥuŋ
aŋ	+	+	+	-	

əi	+	T	T	T	jəi = ji, wəi = wi, ɥəi = ɥi
ai	+	+	+	-	
əu	+	T	T	T	jəu = ju, wəu = wu, ɥəu = ɥu
au	+	+	-	-	

In (12) I have listed the equivalent pairs under G-Spread and Triphthong Raising on the right. Under G-Spread I indicate the GV form with 'G' and the V form with '+'; the actual pronunciation is usually the GV form. Under Triphthong Raising I use 'T' to indicate the form with a mid vowel and '+' (or '-' if absent) to indicate the other form; in actual pronunciation either form may be used.

Of the remaining cells, 35 are found and 9 remain unaccounted for, shown in (13). In is worth noting that 8 of the 9 unexplained forms contain [ɥ]. It may be possible to find another (language-specific) constraint, but I will leave it open for now.

(13) Unexplained missing forms (9 in all)

ɥi ɥin ɥu ɥuŋ ɥa ɥaŋ ɥai ɥau wau

This concludes the analysis of Mandarin. A summary is given in (14). It can be seen that more than half of the missing forms are ruled out by Rhyme Harmony and Merge, which are probably universal constraints.

(14) Summary of the analysis of Mandarin

Reason	Number of missing forms
Rhyme Harmony	28
Merge	8
G-Spread	6
Triphthong raising	10
*GY	4
Gaps	9
Total	65

86% of all missing forms are explained
91% of all possible forms are explained

In the next section I show that the same analysis can be applied to Shanghai Chinese.

3. Shanghai

In this section I examine Mainstream Shanghai (hereafter Shanghai), which is the majority dialect spoken in Shanghai City (Xu et al. 1988). The GVX forms in Shanghai are shown in (15), from Xu et al. (1988: 8).

(15) Shanghai GVX forms: 38 (plus 5 syllabic consonants [z r m n ŋ])

	i	u	y
A	iA	uA	
ɔ	iɔ		
o			
ɤ	iɤ		
ɛ	iɛ	uɛ	
ø		uø	yø
ã	iã	uã	
ɑ̃	iɑ̃	uɑ̃	
ən	in	uən	yn
oŋ	ioŋ		
Aʔ	iAʔ	uAʔ	
oʔ	ioʔ		
əʔ		uəʔ	
	iɪʔ		yɪʔ

The list invites many questions. For example, how should we interpret the transcription? How many vowels are there? How many final Cs are there? Can we account for the GVX forms that are used and those that are missing? Unfortunately, Xu et al. offer no further composition of the GVX forms. Indeed, there has been no systematic study of the syllable in Shanghai.

In order to examine the constraints on GVC, we need to determine the phonemes. There are two possible analyses. The first assumes that all vowels that occur alone are independent phonemes. On this view, only C can occur after V. The shortcoming is that [ɔ ø ɛ] have restricted use and allow no consonant after them. The second analysis assumes that [ɔ ø ɛ] are not underlying vowels but derive from diphthongs ([au], [əy] and [əi] respectively). On this view, the underlying representation is more abstract. I discuss each analysis in turn.

3.1. Analysis 1: [ɔ ø ɛ] are independent phonemes

Assuming that all vowels that occur alone are independent phonemes, I propose the interpretations in (16) through (21), and the resulting GVC list in (22).

(16) Questions about [a/A]:
[a/A] are in complementary distribution
Proposal: [A] = [a]

(17) Questions about [ɛ]:
There is no [e]
Proposal: [ɛ] = [e]

(18) Questions about [ɤ] and [ə]:
[ɤ] and [ə]are in complementary distribution
Proposal: [ɤ] = [ə]

(19) Questions about [ɑ] and [ɔ]:
[ɑ] and [ɔ] are in complementary distribution
Proposal: [ɔ] = [ɒ]
[ɑ̃] = [ɒ̃]

(20) Questions about [ɪ]:
[ɪ] only occurs in [iɪʔ] and [yɪʔ]
There is no contrast between [i] and [ɪ], or between [ɪ] and [y]
Proposal: [iɪʔ] = [iʔ]
[yɪʔ] = [yʔ]

(21) Questions about [n], [ŋ], and [˜]:
[n], [ŋ], and [˜] are in complementary distribution
Proposal: There is only one nasal N, unspecified for place

(22) Revised GVX list:

i	y	u	e	ø	ə	o	a	ɒ
ia	ua	aN	iaN	uaN	aʔ	iaʔ	uaʔ	
iə	əN	uəN	əʔ	uəʔ				
oŋ	ioN	oʔ	ioʔ					
iɒ	ɒN	iɒN	uɒN					
ie	ue							
uø	yø							
iN	iʔ							
yN	yʔ							

The revised members of G, V, and C are shown in (23), and the complete GVC table is shown in (24). When two GVC forms are similar, such as [uN] vs. [oN], it is sometimes not obvious which one should be marked with ‘+’. This should be clarified below.

(23)	G:	[i u y]	
	V:	[i u y a ɒ o ə e ø]	
	C:	[ʔ N]	(N is a nasal unspecified for place)

(24)			0-	j-	w-	ɥ-	
	[-0]	i	+	(+)	-	-	ji = i
		u	+	-	(+)	-	wu = u
		y	+	-	-	(+)	ɥy = y
		e	+	+	+	-	
		ø	+	-	+	+	
		ə	+	+	-	-	
		o	+	-	-	-	
		ɒ	+	+	-	-	
		a	+	+	+	-	
	[-N]	iN	+	(+)	-	-	jin = in
		uN	-	-	-	-	
		yN	+	-	-	(+)	ɥyn = yn
		eN	-	-	-	-	
		øN	-	-	-	-	
		əN	+	-	+	-	
		oN	+	+	-	-	
		ɒN	+	+	+	-	
		aN	+	+	+	-	
	[-ʔ]	iʔ	+	(+)	-	-	iʔ = jiʔ
		uʔ	-	-	-	-	
		yʔ	+	-	-	(+)	yʔ = ɥyʔ
		eʔ	-	-	-	-	
		øʔ	-	-	-	-	
		əʔ	+	-	+	-	
		oʔ	+	+	-	-	
		ɒʔ	-	-	-	-	
		aʔ	+	+	+	-	

Actual ‘+’ = 38 (35% of all); Missing ‘-’ or ‘(+)’ = 70; Total = 108

To account for the missing forms, I assume the same constraints as those in Mandarin, repeated in (25).

(25) Constraints on GVX forms:
Rime Harmony
Merge
G-Spread
Triphthong Raising (applying to GVN and GVʔ)
*GY

Since the only endings are [N ʔ], they are unspecified for [back] and [round], and Rime Harmony and Merge have no effect. G-Spread and *GY do apply. In addition, I assume that Triphthong Raising also applies to GVN and GVʔ. The effect of Triphthong Raising on GVN is not unusual; it is found in some southern American English dialects where the contrast between [pɪn] 'pin' and [pɛn] 'pen' is lost. The effects of Triphthong Raising (T), G-Spread (G), and *GY (Y) are shown in (26)-(28).

(26)

	0-	j-	w-	ɥ-	17, 5, 14 (found, explained, unexplained)
i	+	G	-	-	
u	+	-	G	-	
y	+	Y	Y	G	
e	+	+	+	-	
ø	+	-	+	+	
ə	+	+	-	-	
o	+	-	-	-	
ɒ	+	+	-	-	
a	+	+	+	-	

(27)

	0-	j-	w-	ɥ-	12, 17, 7 (found, explained, unexplained)
iN	+	G	-	-	
uN	G	+	+	-	[uN] = [wuN]
yN	+	Y	Y	G	
eN	-	T	T	T	same as the [iN] row
øN	-	T	T	T	same as the [yN] row
əN	+	T	T	T	[jəN]=[jiN], [wəN]=[wuN], [ɥəN]=[ɥyN]
oN	+	T	T	T	same as the [uN] row
ɒN	+	+	+	-	
aN	+	+	+	-	

(28)

		0-	j-	w-	ɥ-	9, 17, 10 (found, explained, unexplained)
	iʔ	+	G	-	-	
	uʔ	G	+	T	-	[juʔ] = [joʔ], [wuʔ] = [wəʔ]
	yʔ	+	Y	Y	G	
	eʔ	-	T	T	T	same as the [iʔ] row
	øʔ	-	T	T	T	same as the [yʔ] row
	əʔ	+	T	+	T	[jəʔ] = [jiʔ], [wəʔ] = [wuʔ], [ɥəʔ] = [ɥyʔ]
	oʔ	+	T	T	T	same as the [uʔ] row
	ɒʔ	-	-	-	-	
	aʔ	+	+	+	-	

Altogether 39 cells are ruled out, and 31 cells remaining unexplained, shown in (29).

(29) Unexplained missing GVX forms (31 in all)

wi	ɥi	ju	ɥu	ɥe	jø	wə	ɥə	jo	wo	ɥo
wɒ	ɥɒ	ɥa								
wiN	ɥiN	ɥuN	eN	øN	ɥɒN	ɥaN				
wiʔ	ɥiʔ	ɥuʔ	eʔ	øʔ	ɒʔ	jɒʔ	wɒʔ	ɥɒʔ	ɥaʔ	

This list is longer than that in Mandarin, and further generalizations seem possible. For example, nearly half of the missing forms contain [ɥ] (15 out of 31). In addition, some missing forms seem to form sets, such as [wi]-[wiN]-[wiʔ], [ɥi]-[ɥiN]-[ɥiʔ], and [ɒʔ]-[jɒʔ]-[wɒʔ]-[ɥɒʔ]. However, for lack of space, I leave further improvements for future research.

This concludes the first analysis of Shanghai. A summary is given in (30). The percentage of unexplained forms is higher than those in Mandarin but more than half of the missing forms are accounted for.

(30) Summary of the analysis of Shanghai

Reason	Number of missing forms
Rhyme Harmony	0
Merge	0
G-Spread	9
Triphthong raising	24
*GY	6
Gaps	31
Total	70

56% of all missing forms are explained
71% of all possible forms are explained

3.2. Analysis 2: [ɔ ø ɛ] are derived from diphthongs

Recall that [ɔ ø ɛ] have restricted occurrences and allow no consonant after them. It is possible, therefore, that [ɔ ø ɛ] are not underlying vowels but derived from diphthongs. Along this line of thought, I propose the interpretation of GVX forms in (31).

(31) Revised GVX list (38 in all)

	i	u	y	
a	ia	ua		A = a
au	iau			ɔ = au
o				
ə	iə			ɤ = ə
ai	iai	uai		ɛ = ai
ay		uay	yay	ø = ay
aN	iaN	uaN		ã = aN
oN	ioN	uoN		ɑ̃ = oN
əN	iN	uəN	yN	n = N
uŋ	iuŋ			oŋ = uN
aʔ	iaʔ	uaʔ		A = a
oʔ	ioʔ			
əʔ		uəʔ		
	iʔ		yʔ	iɪʔ = iʔ; yɪʔ = yʔ

The members of G, V, and C and the numbers of conceivable and actual GVX forms are shown in (32).

(32)

G:	[i u y]	
V:	[i u y a o ə]	
C:	[i u y ʔ N]	(N is a nasal unspecified for place)

Total number of possible GVX rimes: 4G * 6V * 6X = 144
Actual number of GVX forms: 38 (26%)

The analysis of possible and actual GVX forms is similar to that in Mandarin. If we make a full table of GVX combinations in Shanghai, there are 36 rows, of which Rime Harmony and Merge rule out 11 rows, shown in (33).

(33) 11 rows ruled out by Rime Harmony and Merge

*row-oy	differ in [back]
*row-uy	differ in [back]
*row-yu	differ in [back]
*row-iy	differ in [back]
*row-yi	differ in [back]
*row-iu	differ in [back]
*row-ui	differ in [back]
*row-oi	differ in [back]
*row-ii	Merge, [ii] = [i:]
*row-uu	Merge, [uu] = [u:]
*row-yy	Merge, [yy] = [y:]

The remaining 25 rows are shown in (34), where the effects of Triphthong Raising (T), G-Spread (G), and *GY (Y) are indicated.

(34)

		0-	j-	w-	ɥ-	
[-0]	i	+	G	-	-	ji = i
	u	+	-	G	-	wu = u
	y	+	Y	Y	G	ɥy = y
	ə	+	+	-	-	
	o	+	-	-	-	
	a	+	+	+	-	
[-N]	iN	+	G	+	-	jiN = in, wiN = wəN
	uN	+	+	G	-	wuN = uN
	yN	+	Y	Y	G	ɥyN = yN
	əN	+	T	T	T	jəN = iN, wiN = wəN, ɥəN = yN
	oN	+	+	+	T	ɥoN = yN
	aN	+	+	+	-	
[-ʔ]	iʔ	+	G	-	-	jiʔ = iʔ
	uʔ	G	+	+	-	uʔ = wuʔ, juʔ = joʔ, wuʔ = wəʔ
	yʔ	+	Y	Y	G	ɥyʔ = yʔ
	əʔ	+	T	T	T	jəʔ = iʔ, wəʔ = uʔ, ɥəʔ = yʔ
	oʔ	+	T	T	T	joʔ = juʔ
	aʔ	+	+	+	-	

[-i]	əi	-	T	T	T	jəi = i, wəi = wi, ɥəi = yi
	ai	+	+	+	-	ɥai = ɥɛ
[-u]	əu	-	T	T	T	jəu = ju, wəu = wu, ɥəu = yu
	ou	-	T	T	T	jou = ju, wou = wu, ɥou = yu
	au	+	+	-	-	
[-y]	əy	-	T	T	T	jəy = jy, wəy = wy, ɥəy = y
	ay	+	+	+	-	

+ = 38, - = 25, G = 9, T = 22, Y = 6

There are 25 cells that are unexplained, shown in (35).

(35) Unexplained missing forms so far (25 in all)

wi	ɥi	ju	ɥu	wə	ɥə	jo	wo	ɥo	ɥa	ɥiN
ɥuN	ɥaN	wiʔ	ɥiʔ	ɥuʔ	ɥaʔ	əi	ɥai	əu	ou	wau
ɥau	əy	ɥay								

This list is shorter than that in the previous analysis but still longer than that in Mandarin. Again, further generalizations seem possible. For example, over half of the missing forms contain [ɥ] (14 out of 25). In addition, some missing forms seem to form sets, such as [wi]-[wiʔ], [ɥu]-[ɥuN]-[ɥuʔ], and [ɥi]-[ɥiN]-[ɥiʔ]. However, for lack of space, I leave further improvements for future research. In (36) I summarize the analysis.

(36)

Reason	Number of missing forms
Rhyme Harmony	32
Merge	12
G-spread	9
Triphthong raising	22
*GY	6
Unexplained	25
Total	106

76% of all missing forms are explained
83% of all possible forms are explained

4. Concluding remarks

The present study illustrates several points. First, the list of actual syllables used in Chinese is only a small fraction of all conceivable combinations. Second, most of the missing syllables can be accounted for by a small set of constraints. Some of the constraints seem to have a physiological basis and are probably universal. Other constraints seem to facilitate articulatory ease but are not universal. Third, there is considerable difference between the syllable structure in Mandarin and that in Shanghai, but both can be analyzed with similar constraints.

The present analysis has implications for syllable theory in general. It is possible that in all languages the number of actual syllables is just a small fraction of all conceivable syllables. When we look at actual and missing syllables in a language, we should keep in mind two kinds of constraints, those that are universal and those that are language specific.

The analysis also has implications for the reconstruction of historical phonology. When sound change occurs, not every conceivable syllable is available for an existing syllable to change into. In fact, at any moment probably just a small fraction of all conceivable syllables are available for existing syllables to change into. The lack of useable syllables is a possible reason why sound changes often become irregular.

Finally, the present analysis has implications for the theory of language universals. Chomsky (1986) argues that much of our linguistic knowledge is innate and this innate knowledge is the same in all languages. In addition, Chomsky argues that there is a designated language faculty in the brain, where the innate linguistic knowledge resides. However, the constraints Rime Harmony and Merge are likely to hold for all languages, yet they do not seem to be related to language alone. Instead, they seem to be the result of a general physiological limitation on how fast muscular activities can take place. If so, we should recognize additional language universals, in phonology at least, that do not originate from a language faculty.

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