Mandarin Chinese Phonemics and the X-bar theory of GP*

The Challenge of Systematic Gaps

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1. Introduction

Mandarin Chinese has (rarely, but consistently) been a challenge to phonological theories, in particular with respect to the notion of abstractness. Theories which refer to phonemes even in the broadest sense encounter severe conceptual problems. Therefore the first conjunct of our title should read with an ironic undertone. We will show that an analysis in terms of Government Phonology, using pre-existing, independently motivated universal principles, can give a minimal and systematic representation of the phonological units of Mandarin. Second, phonotactic restrictions fall out quite naturally in that model and third, gaps in the system of finals of Mandarin can be incorporated into broader generalisations. Lexical tone will be an integral part of the model of phonological representation, and finally we will provide an analysis of '*-er*' suffixation in the Beijing dialect as a floating element which attaches to the structure, without superimposing an additional process.

2. The phonetic inventory of Mandarin

In many traditional descriptions of the phonological system of Mandarin Chinese, mono-morphemic words are systematically analysed as consisting of two parts: onsets and finals. Onsets are quite straightforwardly what common frameworks would regard as onsets, finals on the other hand are rather complex entities. Basically they split into four groups depending on the 'glide' that constitutes the first part of the final: [i/j], [u/w], [y] or none. Apart from these glides, a final in Mandarin Chinese can contain a simple vowel, a diphthong or a combination of a simple vowel and a nasal (consonant). Since diphthongs and vowel-plus-nasal combinations are in complementary distribution, we will discern four slots into which phonological material can be stacked. Pre-theoretically these are 2 onset-like positions and 2 nucleus-like positions, whereby the second nucleus position can also contain nasals.

(1) The traditional template:

x1	(x2)	x3	(x4)
onset	glide	nucleus	diphthong material, nasal

In the following we will give an outline of the phonetic inventory of Mandarin Chinese.

2.1. Onsets and glides

Let us start with the set of onsets. (Transcriptions follows han-yu pin-yin standards.)

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(2) x1: onsets:

	neutral	aspirated	nasal	fricative
labial	*b* [p]	*p* [p^{h}]	*m* [m]	*f* [f]
coronal[1]	*d* [t]	*t* [t^{h}]	*n* [n]	see below
alveo-dental	*z* [ts]	*c* [ts^{h}]		*s* [s]
retroflex	*zh* [tʃ]	*ch* [tʃ^{h}]		*sh* [ʃ]
palatal	*j* [tɕ]	*q* [tɕ^{h}]		*x* [ɕ]
velar	*g* [k]	*k* [k^{h}]	*	*h* [x]
liquid	*l* [l], *r* [ɻ]			
glide	*y* [j], *w* [w], (*ü* [y])			

This list is quite self-explanatory, but a few remarks seem to be in order. We find the common three-way distinction of place features: except for liquids and glides, every onset can be assigned to one of the places velar, coronal or labial. As for manner, only stops (and affricates) can be plain or aspirated. The fortis/lenis distinction is expressed by the feature 'aspiration' rather than 'voicing'. The fricatives can also be assigned to the three places, but note that there is only **one** velar and labial fricative (*h*-, *f*-), while the coronal fricatives display an additional **three**-way contrast: neutral (*s*-), palatal (*x*-) and darkened (*sh*-). The nasal series is defective: the velar nasal is excluded from appearing in onset position, but it is present in the final nasal/diphthong position x4 (where, in Mandarin, a labial nasal is excluded). The liquid *l*- and nasal *n*- can be palatal, *r*- is a retroflex approximant. The glides only appear as onset if there is no other onset available; otherwise they will apparently show up in position x2.

(3) x2: glides: *y* [j], *w* [w], *ü* [y]

The glides in Mandarin Chinese are basically the ones found in numerous languages: [j] and [w]. The special item is an [y]-glide, as a combination of the two other glides. The question is, whether they should be analysed as belonging to the onset (forming palatalised or labialized consonants), or to the nucleus (yielding diphthong, or even triphthong structures.) '*bian*' could be analysed as [b^{j}æn] or [bi͡æn], '*guai*' as [g^{w}ai] or [gu͡ai]). If the glide is followed by the same phonological entity (i or u), it will apparently be realised as a true vowel (e.g. *qing* [tɕ^{h}iŋ]). However, in the light of phonotactic restrictions between onsets and glides, we will assume that glides are actually part of the onset, i.e. the word-initial consonant.

We have already mentioned that [y] is a combination of the characteristics of /i/ and /u/ together. This phoneme does not have a non-high counterpart. If we allow for /i/ and /u/ to combine, we might expect to find a combination with the characteristics of /a/, yielding a phoneme comparable to [ø] or [œ], which we find for example in German, French, Hungarian or Turkish. But the distribution of [y] in Mandarin is highly restricted: it only appears with palatalised fricatives, n, l or zero-onsets, and it also requires the following final material to contain some i-characteristics. The class of finals where [y] appears consists of precisely four entities: *-ü*, *-üe*, *-ün* and *-üan*. An explanation for this, which also accounts for the lack of non-high front rounded vowels in Mandarin, will be given in section 4.2.1.

[1] 'Coronal' is not really meant here as a phonetic label, rather it is used as a cover term in order to oppose it to the two other groups 'labial' and 'velar'.

2.2. Nuclei and x4

The last two positions, x3 and x4, should not be considered in isolation. This is not to say that they form a unit of some sort, but the interactions between phonological entities located in these positions are quite complex, even though they result in a seemingly arbitrary list of possible finals.

(4)	x3:	nuclei:	a, e (i), o (u), [ɚ], [ɨ] ([ɻ̩])
	x4:	nasal/diphthongs:	i, u (o), n, ng [ŋ]

Notice that x4 can only be occupied by i/u (glides) and nasals. This strongly indicates that it is a true 'coda' position rather than a vocalic diphthong site. Also interesting is the fact that other dialects of Chinese and earlier stages of Mandarin even have stops in this position (some of them interacting with tone).

3. Revised Government Phonology

The decision for a particular theoretical model will crucially affect the mere description of the phonological data of a given language. In the case of Mandarin we should address two questions first: what is the metrical structure of monomorphemic words and which phonological primitives exist with which to give every sound in a language a particular representation? For the first question we will assume a bisyllabic structure for monomorphemic words in Mandarin, with the further restriction that every syllable (henceforth: syll) consists of a monadic pair CV (or ON) (cf., Lowenstamm, 1999). The system of phonological primitives is a slightly modified version of the traditional elements of Government Phonology (cf. KLV (1985, 1989), Harris (1990), Rennison (1996), Neubarth & Rennison (1998)).

In the following we will give a brief outline of the axioms of our brand of phonology in terms of standard Government Phonology.

- There is a restricted set of elements which constitute the melodic primitives of the phonological system of every language. They are atomic, meaning that they cannot be decomposed into smaller features. The set of primitives is finite, universal and minimal. The primitives themselves are fully interpretable, each of them, or any combination of them, has a phonetic output.
- The primitives are I, U, H, L, R and the functional element F. (This element was previously referred to as the 'empty' element,[2] cf. Rennison, 1997.) The following table shows the elements and their phonetic correlates, and a comparison to the elements previously used in Government Phonology.

[2] The previous terminology led to some confusion between an empty element (within melody) and empty structure (with no melody). We hope that the new terminology will alleviate this; note however that this terminological change involves no change in the substance of our theory.

F functional: affects melodic content according to position (C/O or V/N) and function (head or operator).[3]

head of	C/O:	stop[4]	standard GP:	→	ʔ
	V/N:	low		→	A
operator of	C/O:	spirant[5]		→	h
	V/N:	tense		→	ATR

I front/high/palatal
U labial/rounded/dark
L nasal/voiced (lenis) / low tone
H friction/aspirated (fortis) / high tone
R liquid/coronal

- Every skeletal point can either be empty, or have melodic material (elements) attached to it. Whenever melodic material is present in a slot, there is at least one head. There are no unheaded melodic structures whatsoever. When an element is not head it is interpreted as an operator, which means that it modifies the interpretation given by the head. Heads are symbolised by underlining, and are located on the left of a melodic expression; operators appear after a comma. (e.g. C[F,RH] will be an aspirated/fortis coronal stop - [t^h].)
- Notice that, except for the functional element, it makes no sense to modify a head with the same element. An operator equal to the head cannot contribute any further information. On the other hand, there is an additional asymmetry between the functional element and the others: if it should encode the information of 'stop' or 'low' it has to be the head of the expression. This is the main difference vis-à-vis the standard GP model, where the ʔ and the A element were free to be head or operator and where unheaded expressions were also allowed. In this respect the model presented here is fundamentally more restrictive than previous ones.
- The interpretation of melodic material of a certain skeletal point crucially depends on whether that position is a consonant or a vowel. In traditional phonemic terms, one might think that C and V also bear some melodic status. However, we prefer to think that this theory takes the autonomy of syllable structure seriously.[6]

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[3] The actual phonetic correlate of the functional element as head could be characterized as 'give the default signature of vowel/stop', i.e. a spectral maximum in the middle of the frequency scale or silence. To find a correlate of F as operator is more difficult, per definition it should 'modify' or 'distract' from the signature given by the head. The case of spirantized consonants is quite straightforward: the amount of 'silence' is drastically decreased. ATR-vowels are not so easily aligned to that formulation. If there is an F-head present, an F-operator weakens the a-characteristics (as in ɔ-o, ɛ-e), but if U or I are heads we should specifically know what their vocalic signature is. Cf. Harris & Lindsey (2000).

[4] Note that there is a big difference between the notion 'stop', which also has a clear acoustic correlate, and 'occlusion', which is purely articulatory and has no significant correlate, since nasals would also (unnaturally) fall under that description.

[5] One has to bear in mind that 'spirantization' is a rather descriptive term. The process of spirantization is a classical lenition process, but it would be surprising if it were regarded as addition of an element (the functional operator) to the melodic structure. What we have in mind here are rather spirants as part of phonemic systems, like [θ,ð] in languages like English, Arabic or Greek.

[6] The consequences of our F element, among others, are that a stop can never appear in a nucleus (which was not excluded in principle by any previous theory of phonology) and that [a, e, o] (i.e. vowels with the A element) can never appear in an onset. [i, u, y], on the other hand, are not excluded from the onset position (where they are the glides [j, w, ɥ]).

- Consonants may have (and possibly must have, universally) any of the elements as a head; the complexity of the sound system of a given language may be described in terms of parametric requirements for, or combinatory restrictions on, operators and heads.
- Vowels superimpose some additional (presumably universal) restriction: only I, U and F may function as heads of a vowel. R is genuinely consonantal; it is prohibited in the lexical representation of any vowel. Rhotacized vowels may arise from some phonetic process indicating that a weak R-head with no operators is present in the following (onset) constituent. This is also true for some nasal(ised) vowels (with an L-operator), e.g. in French.[7] H-operators will represent lexical tone. The F-operator in vowels represents the ATR (tense/lax, open/closed) contrast.[8]
- Having more than one head in a melodic expression yields multiply headed structures. Labialized or palatalised consonants and affricates can be represented as contour segments where all the melodic material is attached to one skeletal point. Note that this interacts with the reduction convention: we will not find aspirated fricatives, but if there are aspirated stops in a language, it is possible to find aspirated affricates as well, which is exactly the case in Mandarin Chinese.
- The basic phonological unit is a syll ($\overline{x}$) (cf. Neubarth and Rennison 1998), which is a pair of two skeletal points (x), one being an Onset/Consonant the other a Nucleus/Vowel (ON/CV). More complex structures can only be generated by adding more sylls.
- Every syll has a numerical value[9] which is calculated from the values of the elements in C-position. Whether an empty V-position can remain phonetically uninterpreted depends on certain (parameterised) factors, all of them related to one notion: government from syll to syll, from right to left. The options are whether a syll can govern a syll to its left a) always, b) if V has melodic content or if it is unlicensed (V-to-V government) c) if its numeric value is higher (C-to-C government). A special context is the beginning and the end of a phonological domain. Languages can parametrically demand special licensing requirements: FEN (final empty nucleus) is virtual government from the possible next phonological expression, FFN (first full nucleus) is the mirror image: it regulates possible government capacities for a preceding (virtual) FEN. Note that these notions are not necessarily related to each other. German would have the options FEN: as if V-to-V government (no restriction on consonants at the end of domain). FFN: both V-to-V government and C-to-C government which behaves as if the preceding onset were empty (i.e. the glottal stop, val=10). Therefore we find only restrictions on consonant clusters – i.e. the first C of a cluster must be strong enough, the cluster itself is licensed like any other cluster in German.

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7 Languages with context-free nasal vowels will probably not lend themselves to such an analysis.

8 That we need a coding for ATR-contrast seems to be necessary even in languages like German, where the contrast is apparently attributable to the length of the vowel (e.g. [e:] - [ɛ], [i:] - [ɪ] etc.). Non-Germanic words, which show all kinds of stress-shift, have vowels reduced by length but with the same quality (Mu'sik [mu'zi:k] - 'Musiker ['mu:zikɐ]).

9 The actual calculus does not play any role on the topic presented here. Just for information: the inherent values of elements are: F=0, I/U=1, L/H=3, R=5. There is a basic constant value of 10 (double the maximum value of a single element, i.e. 2*5) and the value of a certain consonant results from substracting the value(s) of the head and adding the values of the operators. (val(C) = 10 - Σval(head) + Σval(op)). If this is true for all classes of consonants or if certain heads (maybe I,U and L) take only their head-value as the basis (val(C) = val(head) + Σval(op)) is an open matter to be decided. The licensing mechanism of C-to-C government in this model can be illustrated with word final consonant clusters in German. One example would be '*Herbst*', with four consonants before the end of the word. The last C is licensed by virtue of FEN-licensing, but the other three must meet the requirement that each of them is weaker than the following.

val(r[R]) = 10 - 5, val(b[F,U]) = 10 - 0 + 1, val(s[H,R]) = 10 - 3 + 5, val(t[F,R(H)]) = 10 - 0 + 5 (+ 3)
Herbst: r - b - s - t : 5 < 11 < 12 < 15(18).

Cf. Rennison & Neubarth (1998), where a minimally different version of C-to-C government is discussed.

4. An analysis in terms of GP

4.1. Onsets

At this point we have the tools necessary to attempt a systematic description of the sounds of Mandarin Chinese. Let us start with the consonant system first. One basic assumption is that one finds each of the elements as a head (perhaps universally). This gives us the velar stop [k/g] ([F]), fricative [x] ([H]), and nasal [ŋ] ([L]), an *i*- and *u*-glide [j] ([I]) and [w] ([U]) and an r-like liquid, which in Mandarin shows up as a retroflex approximant [ɻ] ([R]). R and U as operators in consonants function as place determiners. (Notice that R is asymmetrically stronger than U, that means that if both are present in a melodic expression, R will determine the place and U can only contribute 'darkness'.) The phonetic correlates are 'labial' and 'coronal'. The fortis-lenis distinction in stops is encoded by the presence or absence of H as an operator, which is a standard assumption. When the R-head has U as an operator, the interpretation is not a 'labial liquid' but the lateral [l], since R blocks U from functioning as a place determiner. The glides may not take any operators. I and U as heads tend (perhaps universally) to stand alone in consonant position, though they may combine with one another. The fricatives pose an interesting case, illustrating how languages play around with combinatory possibilities: the H-element as head alone will be velar [x]. Just U as operator yields the labial fricative [f], just R as operator gives us [s], whereas both of them attached to a H-head will be interpreted as the 'dark' [ʃ]. H additionally as operator has no effect, L attached to H-head would give us voiced fricatives, but this option is not used in Chinese. What the functional element as operator would do to a H-head is quite unclear, but notice what happens with I: it has to host on an R-operator and gives us the palatal series.

Finally we can combine heads. At least with coronals, the functional element and the H-element can co-occur in the same position. Guided by universal conditions, the phonetic serialisation will be stop - fricative (F-H) and the interpretation as an affricate. Notice, however, that this is not a mere combination of two sounds but just the instantiation of the H head to be added to the functional head when R is present as an operator. The following table gives the phonetic and phonological representations of all the consonants found as onsets in Mandarin Chinese.[10]

[10] There is one onset missing from that list, the velar nasal. We would like to argue that consisting of just a bare nasal head (L) with no operators it is too weak to form a proper onset. However, it will show up in the second onset position as part of the vowel-nasal combinations. Notice that it can be argued also for other languages that velar nasals never show up in a single onset position, for example in German it can be shown that they only occur in classic geminate context or as a result of assimilation.

(5)

b	[p]	[F,U]	*zh*	[tʃ]	[FH,RU]
p	[p^{h}]	[F,UH]	*ch*	[tʃ^{h}]	[FH,RUH]
m	[m]	[L,U]	*sh*	[ʃ]	[H,RU]
f	[f]	[H,U]	*r*	[ɻ]	[R]
d	[t]	[F,R]	*j*	[tɕ]	[FH,RI]
t	[t^{h}]	[F,RH]	*q*	[tɕ^{h}]	[FH,RIH]
n	[n]	[L,R(I)]	*x*	[ɕ]	[H,RI]
l	[l]	[R,U(I)]	*g*	[k]	[F]
z	[ts]	[FH,R]	*k*	[k^{h}]	[F,H]
c	[ts^{h}]	[FH,RH]	*h*	[x]	[H]
s	[s]	[H,R]	*y*	[j]	[I]
			w	[w]	[U]

There is one more thing to mention with palatals. We will see in the next section that palatal and non-palatal fricative/affricates are in complementary distribution with respect to the classes of finals they may combine with. There is also diachronic evidence that palatal fricatives have emerged as the palatal variant of velars and coronal fricatives. In order to give them a unique representation we assume that synchronically they correspond to the coronals. For this there is evidence from the Taiwanese variant of Mandarin, where all three classes of fricatives merge to one, and not surprisingly, to the unmarked one, the coronal fricative [s]:

(6)

s [s], *sh* [ʃ], *x* [ɕ]	→ [s]	[H,R], [H,RU], [H,RI]	→ [H,R]
z [ts], *zh* [tʃ], *j* [tɕ]	→ [ts]	[FH,R], [FH,RU], [FH,RI]	→ [FH,R],
c [ts^{h}], *ch* [tʃ^{h}], *q* [tɕ^{h}]	→ [ts^{h}]	[FH,RH], [FH,RUH], [FH,RIH]	→ [FH,RH]

4.2. Finals

Melodic material of finals is distributed over several segmental positions. Material from the first or second onset can still affect the interpretation of the nucleus in between. For example I/U elements in the first onset (O1), which clearly are interpreted as glides, with a corresponding element in the second onset (O2) will form a 'bridge' over N1 - the I/U-operator will align to melodic material in N1. This is different from spreading in that it is non-directional. For an exhaustive list of possible finals in Mandarin, see Appendix 2; for a table of all onset-final combinations occurring in Mandarin, see Appendix 1. The 'bridge'-constellations will be indicated by the I/U elements within brackets in the first nucleus.

At first glance the whole table of onset-final combinations is a rather complex and obscure pattern of existing and non-existent forms. In order to gain some insight into these apparently arbitrary phenomena, we will first systematically derive the set of all possible finals from simply trying out every combinatorial possibility between the elements which are permitted to occur in the respective slots. It will be shown that doing so gives us precisely the full set of finals of Mandarin. In a further section we will explore the formal possibilities of that system in order to give explanations to the co-occurrence restrictions, the shaded fields in Appendix 1, taking the challenge of finding a coherent explanation of those gaps.

4.2.1. Combinatorial possibilities

Let us start by trying to impose some restrictions on specific skeletal slots within a Chinese word and to develop a system of possible combinations. A simple characterisation would be that first, N_2 is always empty in Mandarin, licensed as a final empty nucleus. Second, N_1 can only be occupied by the functional element F, otherwise it is empty of melodic content of its

own. This means that any I or U characteristics of Chinese vowels will come from outside, in particular from O_1 or O_2. Third, specific classes of onsets (to be characterised below) allow for a palatalised or labialized variant, corresponding to the 4 classes of finals (without a glide, with an [i], [u] or [y] glide). Finally, all combinations of I/U in either of the onset positions are possible, whether F is present in N1 or not.

Notice that in previous analyses or systematisations these glides have been regarded as part of the vowels,[11] hence finals. In this model they are unmistakably part of O_1, showing up as additional operators (or heads). The O_2 position is very weak: the strong heads F and H are excluded, and only I,U,R and L may occur. An R head in O_2 normally excludes any other melodic material in any other position. Therefore we find only one word with R in O_2 in Standard Mandarin, '*er*' ("son") [ɚ]. In the Beijing variant, however, many words will be rhotacized, therefore R in O_2 shows up in many other configurations. See section 6 for further details.

Leaving aside R and the nasals (L) in O_2 for a moment (they do not interact with the material of O_1 and N_1) there are 18 combinatory possibilities, as can be seen in the following table. ('_' indicates that there is no melodic material present in that slot. N_2 is omitted because it is always empty. O_1 can contain melodic content on its own, only additional I and U heads are indicated. For phonetic transcriptions see Appendix 2.)

(7)

O_1	N_1	O_2	*final*	O_1	N_1	O_2	*final*	O_1	N_1	O_2	*final*
_	_	_	*-e*	I	_	_	*-i* *	U	_	_	*-o* *
_	_	I	*-ei*	I	_	I	*-i*	U	_	I	*-ui*
_	_	U	*-ou*	I	_	U	*-iu*	U	_	U	*-u*
_	F	_	*-a*	I	F	_	*-ia*	U	F	_	*-ua*
_	F	I	*-ai*	I	F	I	*-ie*	U	F	I	*-uai*
_	F	U	*-ao*	I	F	U	*-iao*	U	F	U	*-uo*

The realisation of no melodic material at all is a mid-lowering diphthong-like schwa sound [ɐ̯]. If the N_1 position is empty, the melodic specifications of O_2 will affect the phonetic interpretation of N_1, as can be seen in the case of *-ei*, *ou*. If N_1 is empty, but different elements from the set {IU} are present in O_1 and O_2, the result is a glide + diphthong sequence, unsurprisingly (*-iu* [iɔu], *-ui* [uɛi]). The same elements in O_1 and O_2 form a 'bridge'. This means not only that I _ I and U _ U will be realised as -i and -u, but also that a functional element in N_1 will take over the characteristics of the elements surrounding it. I F I will be realised as [ie], U F U as [uo]. Here we see that the glide will be interpreted according to its melodic specification, the nucleus on the other hand is affected by the melodic material of the following onset which in turn need not be phonetically interpreted on its own.[12] Two combinations are rather mysterious at the moment: I _ _ and U _ _ (indicated by an asterisk). For some reason they should not exist. Analogous to what has been said before, they have to be interpreted as glides. But without phonological material in N_1 and O_2 they have no valid host on which they could act as glides. The expectation is that if they exist at all, they will occur only in very restricted contexts. In fact, this expectation is borne out.

4.2.1.1 U _ _

We need a special representation of the minimal finals of labial onsets (*bo* [bʷɔ] vs. *de* [d̪ɐ̯]). Labial onsets carry an U element (determining the place of articulation). And the schwa-

[11] Cf. especially the GP analysis in Goh (1996).

[12] If this were not so, we would expect to find diphthongs with the same glide before them (i.e. iai or uao). But they do not exist in Mandarin. Any other analysis either has to disregard that problem or attribute it to some obscure version of the OCP. Here it is no problem at all, because the phonological combination exists anyway, and the phonetic interpretation is just no longer diphthong-like.

sound which would be the normal result of no melodic material around is darkened to [ɔ]. Note that *[b^wɔʁ] does not exist. It is not entirely clear whether the U-element responsible for the interpretation is only present as operator or also as additional head. The systematic prohibition of an U-head in labial contexts would suggest the first option. However, we have to account for the presence of *bu* which clearly has an U-head in both O_1 and O_2 (as opposed to *pou* which has U only in O_2). Thus we will assume that an U-head is exceptionally licensed even with labials provided that there is no other melodic material present in N_1 and O_2. (U does not count.)

A supporting argument comes from monomorphemic words in Chinese which do not carry tone: these are functional words and they have no phonological material in O_2. A small sample of these words is given below.

(8) *ma* - Q-particle, *mo(me)* - Q-suffixoid, *le* - aspect particle,
zi (son) - derivative suffixoid, *de* - subordination particle

As far as the mentioned properties are concerned – lack of tone and simple phonological melodic structure – an analysis appears to be plausible which treats these words as consisting only of one CV-pair. (See section 5 for more details on tone.) If this is on the right track then the special status of the combinations under discussion becomes clear.

4.2.1.2 I _ _

The second, I _ _, poses a more difficult problem: it is restricted to non-palatal coronal fricative onsets and r, but exactly this class of onsets prohibits palatalising finals (with I in O_1). The phonetic interpretation is neither a glide or an i-like sound but something like a high-central schwa (with *s*-) or [ɻ] (with *sh*- and *r*-). Note that all of these onsets also have a genuine schwa-final (*re*, *zhe*, *ze* etc.), which results from the interpretation of no melodic material. So the relevant questions to be answered are:

1. What is the phonetic interpretation of I _ _?
2. Why is this constellation restricted to fricatives and *r*?
3. Why do these onsets normally prohibit i-glide finals and what makes them accept just I _ _?

I as an (additional) head in O_1 will normally be interpreted as a glide, phonetically hosted by the following nucleus. If it is backed up by a 'bridge' with an I-element in O_2 it will either affect the interpretation of F in the nucleus, or – if N_1 is empty – it will apparently be realised there. However, if there is no melodic material around to host I, the situation is different. The interpretation must be a neutral sound with no lowering features. In the cases considered here, it is the high-central schwa and some retroflex vocalic sound, depending on the type of onset (in particular there is no special articulatory gesture for the vowel-like sound but phonation.)

The second question must be addressed in phonological terms, and its answer relates closely to an answer to the third question. Later on we will argue that an I-element in the first onset must meet special requirements in Mandarin. As an operator it must 'proliferate' in a certain sense in order to be interpretable. The easiest way to do so is also to have it as a head in the melodic representation of that onset; another possibility is a 'bridge'-constellation with the second onset.

In the same way, an additional I-head must normally be backed up by an I-element functioning as operator. As we will see later on, this is not possible with a variety of onsets, among them the coronal fricatives and *r*-. However, if an R-element is present in the melodic representation and if that element is not pinned down by an F-head, it may license an additional I head with no I operator as 'backup', provided that the I-operator can 'proliferate' into the following constituents. This only the case when the following constituents are devoid

of any melodic material whatsoever. The onsets *n-* and *l-* seem to violate this characterisation, but as we will soon see, these are precisely the two consonants which show up in a palatal and in a non-palatal variant. So if they were to have an I-head, they would certainly also have an I-operator.

4.2.1.3 O_2

Nasals in position O_2 do not display any remarkable behaviour: they do not interact with other material in the positions O_1 and N_1 and they simply enlarge the number of possible combinations by 12. There is one fact to be considered: in Mandarin only coronal and velar nasals are acceptable in O_2. Notice that the coronal nasal could in principle actually be palatal everywhere; its I element would only be interpreted if it formed a 'bridge' with an I in O_1.[13] Then the question arises whether only an L head and its palatal variant are allowed in O_2, while the reverse is true for O_1? The R element could then either be omitted (palatal nasals are generally interpreted as coronal), or it could be added to the structure by "default".[14] We will not decide on that here; both options would work with the analysis presented.

4.2.1.4 The ü-series

Now we have reached the point where we have systematically derived all the finals of Mandarin except for the *ü*-series and the palatal-labial *-iong*. In fact they belong to the same class. Notice that their distribution is strictly restricted to onsets in O_1 which bear (or may bear) a palatalising I element. Those are the palatal fricative *x* [ɕ] plus its affricate correlates and *n* and *l*. The latter show up in a palatal and non-palatal variant in many languages. A second key to the understanding of the *ü*-sound [y] in Mandarin is the fact that phonetically there exists a wide array of vowels and vowel combinations, diphthongs of all sorts, an [y], but no [ø], as mentioned above. The explanation is that no [y] sound appears in any nucleus, because the only element that is permitted in nucleus position is the functional element.

The reason for the special occurrence restrictions of *ü* is the complex interaction between operators and heads. In the model presented here it is an option to have more than one element as head. Whether the palatalising and labialising I and U elements in O_1 should be analysed as heads or operators was not decided up to now. The case in question seems to indicate that at least it is possible to have expressions like [FHU,RHI] in O_1, as in *qü* [tɕʰy]. Palatal fricatives have an I operator in their melodic representation which will be copied as an additional head in order to be licensed. This explains why the i-glide series of finals fully combines with palatal fricatives without exception and why these fricatives do not occur with the non-glide and the u-glide series of finals. But why should they take no U-head?

Actually, this is what happens in the ü-series. Here an U-head is present, hence the I-operator does not show up as an additional head but must forms a 'bridge' with the following O_2. This explains why the number of these finals is so small, namely 4 combinations for each of the 3 palatal O_1s. Only [I] and [L,RI] in O_2 can form this 'bridge', and the only available combinatorial option is whether the functional element is present in N_1. What happens to the U element? It will be interpreted as [y] by virtue of I being an operator, licensed by the I-'bridge'. The resulting finals are *-ü* [y] ([U,I] [_] [I]), *-üe* [yɛ] ([U,I] [F] [I]), *-ün* [yn] ([U,I] [_] [L,RI]) and *-üan* [yæn] ([U,I] [F] [L,RI]).

The onsets *n* and *l* complicate the picture a bit more. As mentioned above, they are the only ones which may take an I-operator freely, and the expectation is that we should therefore

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[13] Thanks to Mathias Böhlinger to point this out to us.

[14] The appearance of coronals "from nowhere" as "default" consonants in many languages can be motivated not, as is generally assumed, by the supposed weakness of coronals, but by the fact that the R element, being barred from nuclei, is the only element which uniquely signals the presence of an onset. In Mandarin, the question is therefore: is there any reason to uniquely signal the presence of O_2?

[15] Thanks to Mathias Böhlinger to point this out to us.

find the same 4 combinations as with the palatals. This is not exactly true: we find *lü*, *nü*, *lüe*, *nüe*, but not **lün*, **nün*, **lüan*, **nüan*. Notice that the sole difference between these impossible combinations and their non-palatal counterparts would be the characteristics of the glide. Nothing else signals the distinction between **lün* and *lun*, **nüan* and *nuan* (**nun* does not exist either).[16]

There is one more puzzle, even harder to understand. The *ü*-sound arises from the fact that in O_1 there is an U-head with an I-operator, and the latter has to be licensed by the 'bridge' to O_2. One more final, which is restricted only to palatal fricatives in O_1, does not fit into the picture so far: *-iong* ([jʊŋ]). There is obviously no I-'bridge' therefore no [y] sound arises, and the material in the constituents following O_1 is rather weak: nothing in N_1 and just the L-head in O_2. How is it possible to have an U-head and license the I-operator of the palatal fricative? Remember that we allowed for multiple heads as a principled option. What then would prevent us from assuming that I and U could both occur as additional heads? This is certainly a quite marked option, and we will expect it to occur only when special requirements are met. First the I element must be part of the melodic representation of that consonant, in particular it must be present as an operator. So we will only find both I and U as heads with palatals. Secondly, in order to provide room for the interpretation of I as a glide, U must be able to proliferate – so there must not be any melodic material in N_1. And third, only the velar nasal in O_2 can prevent the whole constellation to collapse into one of the constellations we had before. (I.e., an I element present in O_2 renders the *ü*-series, an U element builds up an U bridge and we get the same result as with I _ U.) So, only in the case where an L-head resides in O_2 with I and U as heads in O_1 we find that peculiar final *-iong*.

4.2.2. Systematic gaps

At this point we will address the question why the paradigm of onset-final combinations in Mandarin shows so many gaps. The two most prominent gaps are traditionally called labial dissimilation and palatal assimilation. The primary question is what principles may guide elements to show up as operators and/or as (additional) heads in the same constituent. In fact, there are three options. An element X occurs

a) only as an operator
b) as an operator but also as an additional head
c) only as an additional head but not as an operator

The first case is concerned with the phenomenon that labial onsets (*b-*, *p-*, *m-*, *f-*) do not go together with u-glides. There are just two apparent exceptions already mentioned to this, the series with *-u* and *-o*, which have to be distinguished from *-ou*. In the latter case there is no U element in O_1, only in O_2 . This U of O_2 affects the interpretation of the empty nucleus N_1. Remember that we earlier allowed for an U-head in O_1 without any further material for labials (*-o*). In the light of the cases under consideration, we would like to assume that, if U encodes place (i.e. if there is no R-element present in the structure), it is always either operator (labials) or head (u-glides), but never both. We assume that in Mandarin an element encoding primary place must not 'proliferate' further on. Its domain is restricted to the head it is attached to. But if the additional U-head can proliferate into N_1 (guaranteed that it is not disturbed by any other elements in O_2) it can exist independently from the U as operator in O_1 thus avoiding any conflict with it.

I-assimilation is just the reverse behaviour. If I is present in O_1, it will always be operator and head (i.e. case b above). Therefore if we have an I-glide, we have to assume that the onset is palatalised. Thus for the labials, the phonetic interpretation of palatalization is simply: a

[16] Notice that in the paradigm of onset final combinations also **nuai*, **nui*, **luai* and **lui* are systematically absent. We argue that their representation would be exactly what we get with the *ü*- finals with the only difference that the first onset is not palatalized. There seems to be some pressure to harmonize palatal characteristics of the two onsets.

labial with an I-glide. However, this does not apply to labial fricatives. The H-head without an R-operator seems to be too weak to license an additional I-operator. The same holds for an R-head without any additional operators at all (*r*- vs. *l*-). It is harder to argue for the velar series. Diachronically, palatalised velars became coronal palatalised fricatives/affricates. We would have to assume a process that inserts an R-operator whenever a velar contains an I-operator. Is this a plausible assumption? Since this diachronic process can be observed in many languages, we do think so. What about coronals? The interpretation of palatalised coronal stops with respect to I will not be different from their non-palatalised counterparts, but the fricatives change their characteristics and fall into the palatal series. This was a diachronic observation; synchronically, at the present stage of Mandarin Chinese we observe a complementary distribution: palatal and non-palatal fricatives, the former always with an *i*-glide, the latter never combining with an *i*-glide.

4.2.3. More Gaps

The more we would like to understand and analyse the non-systematic gaps of the onset-final chart given in Appendix 1, the more we will encounter idiosyncratic properties of the language. Remember that all the gaps discussed so far were more or less the result of strict conditions which apply to the ability of onsets to take an additional I- or U-element as a head. The remaining gaps are more complex in nature. As a first attempt to impose some classification upon them, we will distinguish between finals which contain the functional head (F) in N_1 and those which do not. (Recall that F is the only melody that is possible in N_1.)

For the gaps which have no melodic material in N_1, there does exist a corresponding form with F (e.g. **tei* vs. *tai*). The cases where this does not hold are **rei* – **rai* and **n/l-uai* – **n/l-uei*. The first seems to be absolutely idiosyncratic. The latter could be explained on a par with the *ü*-finals. The two finals under consideration are the only ones in the labial paradigm which have I in O_2. Under these circumstances (I in O_2, n/l in O_1) there will be an obligatorily I-'bridge', hence we find the forms which ought to fill these mysterious gaps precisely in the *ü*-paradigm (*n/l-uai* → *nüe / lüe*, *n/l-uei* → *nü/lü*).

If we look at that class of gaps without F in N_1 we see that they are quite randomly scattered over the table. There is a slight tendency that fortis-onsets (with a H-operator) are more likely to disallow finals of this class than lenis onsets. The generalisation would be that if there is a gap with a lenis onset we will find a gap with a fortis onset, too, but not vice versa.[17] What has this all to do with the comparison between the gaps with an empty N_1 and their existing counterparts? A possible explanation for those gaps could be that they are actually are in competition with their counterparts and for some reason they merged with them at a certain point in history, leaving a gap. This could be correlated to the previously mentioned tendency that lenis stops, but also nasals and liquids are more resistant to having gaps in their paradigm than fortis stops. Phonetically, the more voice activity there is in the onset itself the more clearly the acoustic pattern of the vowels will be discernible. This, however, is just a speculative idea. Crucially, it is the finals with F in N_1 into which the two classes are merged.

The gaps with a functional head in N1 are much more systematic.[18] In fact they form small paradigms on their own. Affected are finals with an *i*-glide *-ia*, *-iang* (but not *-iao* or *-ian*), and with an *u*-glide *-ua*, *-uai*, *-uang* (but not *-uan*). The palatal ones have gaps with labial and coronal onsets (e.g. **bia*, **diang,* but there is *niang*), the labial finals with coronals, *n*, *l*, *r* (still, there is *rua*) and alveolar fricatives/affricates. This is a rather complex list. Let us try to gain more insight by posing the question which of the onsets do not display gaps. First

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[17] There is one exception to this claim: **bou* vs. *pou*. One could argue that in *bou* the tendency is to enforce an U-'bridge', which implies an U-head rendering *bu*.

[18] Only **fa* (→*fo*)and **fao* (→*fou*) disturb that picture. For some reason they merge to the class without melodic material in N1.

of all velars, secondly 'darkened' (retroflex) fricatives with labial finals, additionally *l-* (and *niang*) with palatal finals.

If we were to ask which existing combination these gaps could be in competition with, it would make sense to compare them to the forms without a glide. Then a possible explanation would be that the functional element in N_1 blocks 'proliferation' of the additional I/U-head under certain conditions. The glide in O_1 needs some extra reinforcement. In the palatal group of finals this is the case if either

- O_1 is itself palatal (*j, q, x, l, n*), or
- O_2 contains melodic material strong enough ([I], [U], [L,R] but not [L] or nothing).

In the labial group of finals an additional U-head will be permitted only if

- O_1 has not much material itself (e.g. velars, which basically have either F or H), or
- O_1 has an R and a U-operator ('darkened' fricatives), or
- there is an U-'bridge' (*-uo*), or
- O_2 contains [L,R].

This is not a purely phonological explanation, but as we have mentioned before, these gaps display just a strong tendency with exceptions here and there (e.g., **nun*, but *rua*). Hence we would not expect to find a general reason to this behaviour by means of a strict phonological process or condition as we did with the systematic gaps. However, the classification and analysis of those gaps and a tentative description of their characteristics can help us to achieve a deeper understanding of phonotactic mechanisms within the model of Government Phonology.

5. Tone

Mandarin Chinese has 4 tones: 1. high: mā, 2. rising: má, 3. low(-rising): mǎ, 4. falling: mà. These could be represented by 2 elements H(igh) and L(ow), which is the traditional assumption on how to represent contour tones. Either every (nucleus) constituent must bear one of the two tonal elements or just every traditional "syllable" (CVCV in our analysis) may just have sufficient tonal information.[19]

(9) option 1: (every N has tone):

```
   H   H     L   H     L   L     H   L
O N O N   O N O N   O N O N   O N O N
```

option 2: (every "syllable" has tone):

```
   H         LH        L         HL
   σ         σ         σ         σ
```

Another possibility, and perhaps the preferable one for an analysis of tone in Chinese languages, is that there is just one tonal element, H, which may, but need not, show up on a nuclear constituent. A four way contour tone system would then look as follows.

(10) option 3: (every N may have tone, but only H as a tonal element)

```
   H   H         H             H
O N O N   O N O N   O N O N   O N O N
```

There is one question that immediately arises with an analysis like this: how come that tone from the second nucleus position, which is always empty (and licensed to be so) will transmit

[19] Notice, that if we permit L to represent low-tone and nasality, this predicts that there are no languages with a nasal distinction of vowels and a tonal system comparable to this one.

freely to the first nucleus position? Diachronic and also comparative facts about Mandarin Chinese and other dialects and languages may help us with the answer to that question. At some stage a whole series of stops was lost from the final position; therefore we find only (quasi vocalic) glides or nasals (n and ŋ) in the second Onset (plus the rhotic *-er*).[20] One could argue that it is exactly this set of phonemes (with strong vocalic characteristics) which permit the free transmission of tone from the second to the first nucleus. Another argument is that it is because of these circumstances that we only find a 4-way distinction of tones.

There is one phenomenon regarding tone in Mandarin Chinese that might shed some additional light on the plausibility of either of the analyses: sandhi. If two (or more) low-rising tone "syllables" - or better morpheme - are adjacent to each other, only the last mono-morpheme maintains its 3rd tone, the others convert into rising tones:

(11)	hěn, hǎo	→	hén	-	hǎo		*'(very) good'*
	wǒ, hěn, hǎo	→	wó	-	hén	- hǎo	*'I am fine.'*
(12)	option 1:	[L L]	→	[L H] / _ [L L]			
	option 2:	σ (L)	→	σ (LH) / _ σ (L)			
	option 3:	[Ø Ø]	→	[Ø H] / _ [Ø Ø]			

Each of these option has its own problems. In the first case we would have to claim that too many low tones must not stay together. In order to motivate this claim, we would have to adopt a very strange version of OCP, since first it would only to L(ow) tone elements but not to H(igh) tone, and second, it should refer to syllable (or metric) structure. (A sequence of falling - low - rising tone "syllables" remains unaffected, e.g. HL - LL - LH.) Option 2 has similar problems, the only advantage is that syllable structure is already encoded in it, but still it would have to refer to the complete tonal representation of the "syllable" and not to neighbouring tonal elements.

If we adopt option 3, the explanation looks rather different. A sequence of four nucleus positions without tonal information, to be more precise, of two metrical units (feet rather than "syllables") calls for a mechanism to fill in phonological (tonal) material. This does not resort on a stipulative principle like the OCP, it just invokes the assumption that tonal information cannot be absent within a certain domain (a sequence of at least two feet).

(13)

			(H)				(H)						
	O	N	O	N		O	N	O	N		O	N	O	N	
	wó				-	hén				-	hǎo				*'I am fine.'*

A challenge to this analysis are languages with more than four contour tones like Cantonese (6 tones) Taiwanese (8 tones) or Vietnamese (5/6 tones). However, those languages have not lost stops in the second onset.[21] Therefore we almost expect that the melodic content in O_2 will affect the realisation of tonal structure, therefore rendering a superficially more complex system.

6. The 'retroflex suffix'

The diminutive suffix '*er*' ('son') combining with certain nouns and adjectives (in the Beijing dialect) gives rise to morphonological change: *diàn-yīng* + *er* → *diàn-yīngr* [tiæn iŋ → tiæn jɐɻ], the rhotic *r* seems to pattern with the *n*, *ng* finals here. Goh (1995) argues against a morphological treatment. He claims that the retroflex forms are non-analytic (=lexical). This

[20] Notice that 'er' as a word has falling tone, in the light of the third option this would mean that it has a H only in first nucleus position, so there is no tonal element which has to spread from N2 over R.

[21] The second onset position is a classical lenition site (cf. Harris, to appear). This also indicates that the Chinese "syllable" = a mono-morphemic word should really be analyzed as a foot.

loses the systematic aspect of the phenomenon. Since the word '*er*' contains only R in the second onset it could be argued that R behaves like a floating element. The only position it can be anchored to is O_2, and by doing so every other head or operator will uninterpreted. (R seems to rather exclude multiply headed melodic structures, and the only operator it takes with effect is U.) In turn the melodic material of the other constituents will be unchanged, the phonetic interpretation will be different though, reflecting a different structuring. In this example there is only an i-glide present in the initial state. The phonetic interpretation will give a vocalic segment with high-front characteristics and no glide will be heard. Merging the R to the template forces the nucleus to be interpreted as a schwa-like sound, the I element in the first onset realises as an i-glide.

(15)

O_1	N_1	O_2	N_2				O_1	N_1	O_2	N_2
|		|		+		→	|		|	
I		L			R			I		R(L)	
	i	ŋ						j	ɐ	ɻ	

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Appendix 1: Table of Initial-Final Combinations in Mandarin Chinese

	a	o	e	i	er	ai	ei	ao	ou	an	en	ang	eng	ong	i	ia	iao	ie	iou	ian	in	iang	ing
b	ba	bo				bai	bei	bao		ban	ben	bang	beng		bi		biao	bie		bian	bin		bin
p	pa	po				pai	pei	pao	pou	pan	pen	pang	peng		pi		piao	pie		pian	pin		ping
m	ma	mo				mai	mei	mao	mou	man	men	mang	meng		mi		miao	mie	miu	mian	min		ming
f	fa	fo					fei		fou	fan	fen	fang	feng										
d	da		de			dai	dei	dao	dou	dan	den	dang	deng	dong	di		diao	die	diu	dian			ding
t	ta		te			tai		tao	tou	tan		tang	teng	tong	ti		tiao	tie		tian			ting
n	na		ne			nai	nei	nao	nou	nan	nen	nang	neng	nong	ni		niao	nie	niu	nian	nin	niang	ning
l	la		le			lai	lei	lao	lou	lan		lang	leng	long	li	lia	liao	lie	liu	lian	lin	liang	ling
z	za		ze	zi		zai	zei	zao	zou	zan	zen	zang	zeng	zong									
c	ca		ce	ci		cai		cao	cou	can	cen	cang	ceng	cong									
s	sa		se	si		sai		sao	sou	san	sen	sang	seng	song									
zh	zha		zhe	zhi		zhai	zhei	zhao	zhou	zhan	zhen	zhang	zheng	zhong									
ch	cha		che	chi		chai		chao	cou	chan	chen	chang	cheng	chong									
sh	sha		she	shi		shai	shei	shao	shou	shan	shen	shang	sheng										
r			re	ri				rao	rou	ran	ren	rang	reng	rong									
j															ji	jia	jiao	jie	jiu	jian	jin	jiang	jing
q															qi	qia	qiao	qie	qiu	qian	qin	qiang	qing
x															xi	xia	xiao	xie	xiu	xian	xin	xiang	xing
g	ga		ge			gai	gei	gao	gou	gan	gen	gang	geng	gong									
k	ka		ke			kai	kei	kao	kou	kan	ken	kang	keng	kong									
h	ha		he			hai	hei	hao	hou	han	hen	hang	heng	hong									
-	a		e		er	ai	ei	ao	ou	an	en	ang	eng		yi	ya	yao	ye	you	yan	yin	yang	ying

	iong	u	ua	uo	uai	uei	uan	uen	uang	ueng	ü	üe	üan	ün
b		bu												
p		pu												
m		mu												
f		fu												
d		du		duo		dui	duan	dun						
t		tu		tuo		tui	tuan	tun						
n		nu		nuo			nuan				nü	nüe		
l		lu		luo			luan	lun			lü	lüe		
z		zu		zuo		zui	zuan	zun						
c		cu		cuo		cui	cuan	cun						
s		su		suo		sui	suan	sun						
zh		zhu	zhua	zhuo	zhuai	shui	zhuan	zhun	zhuang					
ch		chu	chua	chuo	chuai	chui	chuan	chun	chuang					
sh		shu	shua	shuo	shuai	shui	shuan	shun	shuang					
r		ru	rua	ruo		rui	ruan	run						
j	jiong										ju	jue	juan	jun
q	qiong										qu	que	quan	qun
x	xiong										xu	xue	xuan	xun
g		gu	gua	guo	guai	gui	guan	gun	guang					
k		ku	kua	kuo	kuai	kui	kuan	kun	kuang					
h		hu	hua	huo	huai	hui	huan	hun	huang					
-	yong	wu	wa	wo	wai	wei	wan	wun	wang	weng	yu	yue	yuan	yun

Merge columns (*-o* = *-e*, *-ong* = *-ueng*)

Special case '*-er*'

Non-systematic gaps without F in N1

Non-systematic gaps with F in N1

U-dissimilation

I-assimilation

U+I - *ü*-series, *-iong*

Special case *-i* (I _ _)

Appendix 2: Table of phonological representation of finals in Mandarin Chinese

final	phonetic tr.	C_1	V_1	C_2
a	[a]		[F]	
o	[$^{(o)}$ɔ] (labials!)	[U] *		
e	[ɤ]			
i	[ɨ]/[ɻ] (fricatives!)	[I] *		
er	[ɻ]			[R]
ai	[ae]		[F]	[I]
ei	[ei]			[I]
ao	[aɔ]		[F]	[U]
ou	[ou]			[U]
an	[ɑn]		[F]	[L,(R/I)]
en	[n]			[L,(R/I)]
ang	[aŋ]		[F]	[L]
eng	[ŋ]			[L]
ong	[ʊŋ]	[U]		[L]
i	[i]	[I]	[(I)]	[I]
ia	[ja]	[I]	[F]	
iao	[jaɔ]	[I]	[F]	[U]
ie	[je]	[I]	[F,(I)]	[I]
i(o)u	[jou]	[I]		[U]
ian	[jæn]	[I]	[F,(I)]	[L,(R)I]
in	[in]	[I]	[(I)]	[L,(R)I]
iang	[jaŋ]	[I]	[F]	[L]
ing	[iŋ]	[I]		[L]
u	[u]	[U]	[(U)]	[U]
ua	[wa]	[U]	[F]	
uo	[wɔ]	[U]	[F,(U)]	[U]
uai	[wae]	[U]	[F]	[I]
u(e)i	[wei]	[U]		[I]
uan	[wɑn]	[U]	[F]	[L,(R/I)]
uen	[w̃n]	[U]		[L,(R/I)]
uang	[waŋ]	[U]	[F]	[L]
ueng	[ʊŋ]	[U]		[L]
iong	[jʊŋ]	[IU]		[L]
ü	[y]	[U,I]	[(I)]	[I]
üe	[ye]	[U,I]	[F,(I)]	[I]
üan	[yæn]	[U,I]	[F,(I)]	[L,(R)I]
ün	[yn]	[U,I]	[(I)]	[L,(R)I]