Melodic-prosodic duality of the syllable

An application to Chinese

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Implicit in all current theories of the syllable is some assumption of the internal configuration. Prevalent among these are the onset-rime (OR) and the moraic (μ) models, both supported by rather different types of evidence. The OR model favors an interpretation where constituency is exhaustive until the level of the segment which itself is a temporal unit with which melodic features associate. The μ-model distinguishes only what is non-moraic from what is moraic so that sub-syllabic constituency is an accidental result of projecting to/from the same mora. This paper postulates a more fundamental SEGMENT-MELODY complex that projects into two different dimensions: melody and prosody, thus capturing the insights of both the OR and μ-models through the separation of constituency issues with prosodic ones. This approach has direct applications in figuring out two long-standing conundrums in Chinese: the status of the medial glide and the prosodic properties of tonelessness. The SEGMENT-MELODY complex also predicts mismatches in moraicity and syllabicity as well as the mediating effect of the skeletal slots between the melodic root nodes and their moraic status.

Keywords: syllable, mora, foot, segment, feature, prosody

1. Introduction

Implicit in all current theories of the syllable (since Pike & Pike 1947 and Kurylowicz 1948) is some assumption of the internal configuration. Prevalent among these are the onset-rime (OR, Fudge 1969, among others) and the moraic (μ,[1] Hyman 1985; Hock 1986; Hayes 1989, et al.) models, both supported by rather different types of evidence. The OR model favors an interpretation where

1. The mora is probably first articulated by Trubetzkoy (1939), see Broselow (1995).

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constituency is exhaustive until the level of the segment which itself is a temporal unit with which melodic features associate. The μ-model distinguishes only what is non-moraic from what is moraic so that sub-syllabic constituency is an accidental result of projecting to/from the same mora. The μ-model only distinguishes between light and heavy syllables, which aligns better with most prosodic phenomena. The OR model however has an easier time with phenomena, such as ludling and rhyming, that appear to manipulate sub-syllabic strings. With different types of data, analysts have for a long time tried either to account for melodic constituency within a model that recognizes prosodic weight, or to account for prosodic phenomena through melodic constituencies. Such approaches collapse two different concepts (prosody and constituency). This paper proposes that these are different dimensions and that the effects of prosody and constituency are derivable via a more fundamental 'segment-melody' complex that projects in two different dimensions: melody and prosody (first articulated in Srinivas 2016).

This paper attempts to explain how the segment-melody complex may offer new pathways into addressing two difficulties in Chinese phonology: (i) the status of the medial glide and (ii) the nature of tonelessness. §2 gets the ball rolling with an overview of the issues and concepts relevant in the modelling of the syllable. §3 outlines the two difficulties in Chinese phonology of central concern to this paper: the ambivalent status of the medial glide and toneless syllables. §4 fleshes out the segment-melody complex idea and discusses how it offers a window of analysis for issues presented in §3. §5 tests the validity of the segment-melody complex, and §6 offers a conclusion.

2. Basic concepts in the models of syllables

In terms of its physical properties, the syllable is the string of phones/segments between two sonority troughs or valleys, thus in a word like *catnip*, the syllables would be [kæt.nɪp] where the [æ] and [ɪ] are the sonority peaks with sonority falling on either sides of the two vowels. While useful heuristically, something must be said of sonority reversal in examples like *stacks* [stæks] where [s] is more sonorous than [t] and [k], and of the preference for onsets rather than codas in examples like *item* [aɪ.təm]. These issues have been variously addressed in phonological theories that offer algorithms, principles or constraints on what makes a good syllable. The phonological theories however would then have to postulate other abstract units like onsets or moras, both not definable outside their respective theoretical frameworks. An onset is the first constituent of a syllable (in the OR model), while the mora is a unit of syllable weight (in the μ-model). One cannot talk about μ in the OR model, nor can one discuss the constituency of non-

moraic segments in the μ-model. This section does not review the merits of the various models (see Blevins 1995, Broselow 1995, and Srinivas 2016 for comprehensive reviews), but will merely endeavor to present the issues that motivate concepts a good model must necessarily capture.

2.1 Constituency

Constituency at the syllabic level is uncontroversial among phonologists, and can often be identified by where pauses may be inserted. Thus, for a word like *instrumental*, the syllables are [ɪn.stɹʌ.men.təl] and pauses are allowed only at the syllable breaks. Motivation for the syllable as a unit is straightforward, as is evidenced by these being the very units easily counted by speakers of any language which poets among them also manipulate without being trained as a phonologist. Neonatal brains have also been shown to be able to treat syllables differently (Moon & Fifer 1990), and exhibit sensitivity to the differences in positions of syllables that is then used to detect word boundaries (Teinonen et al. 2009). The syllable also serves as the basic domain for many phonological operations such as reduplication.

Evidence for sub-syllabic constituencies appear to be less straightforward. Poetic matching in various ways provides evidence for sub-syllabic constituencies as well: the rime from rhyming, the onset from alliteration and the nucleus from assonance. Typically, rhyming is taken to be indicative that the vocalic nucleus and the post-vocalic consonants are a constituent. This, however, is challenged by rhymes like *tanner:banner:spanner* (Yip 2003).[2] Nonetheless, one wonders if *better* and *rather* do enter into the rhyming scheme, in which case, Yip's observation of rhyme is due the phonetic identity of *-er* in these words, and hence still consistent with the proponents of the rime as a constituent.

Ludling (i.e. play languages, Bagehmil 1988, 1989, 1995; also Chao 1931 for Chinese cases) often involves manipulation of sub-syllabic constituencies. Speech errors provide similar types of evidence. Proponents of the μ-model suggest that the effects of constituency can be likewise captured by a distinction of the moraic from the non-moraic. By this reckoning, spoonerism onset displacement in *the queer old dean* as a reference to *the dear old queen*, is explained away through the non-moraicity of [kw] and [d]. Rhyming would be reducible to the linear identity of the moraic melodies rather than the identity of the rime segments. The μ-camp would predict that in languages where coda consonants are non-moraic, rhyming would apply only to assonance, a position hitherto not verified. To account for

2. For more examples of poetic matching that are not constituents in any theory of the syllable structure, see also Holtman (1996: 203, citing Zwicky 1976).

rhyming as linear identity of moraic melodies would also predict a version of rhyming where moraic melodies of two syllables are identical without sharing a linear order, i.e. *sex* [...eks] and *desk* [...esk]. In English therefore, one would expect three degrees of rhyming strength so that *sex* and *pecks* rhyme strongest (traditionally called masculine rhyme), followed by *sex* and *desk*, followed by *sex* and *let's* (traditionally called assonance or weak rhyme). The expectation does not appear to be vindicated across languages. In any case, even within the μ-model, constituency is possible when multiple melodies are mapped to the same mora.

In short, it is not wise to brush away the insights underlying the need for sub-syllabic constituency.[3]

2.2 Prosodic weight

By and large, languages distinguish only between light and heavy (and maybe super heavy) syllables[4] for the purposes of wordhood qualification and stress/tone assignment. However, the OR model has to remain silent on this front. At the terminal nodes of the OR model is a string of Xs representing skeletal segmental slots. These timing units take their specific phonetic melodies from the bundle of features they are associated with.[5] The corollary to this is that the size of each syllable is determined by the number of skeletal slots, with no distinction as to whether the slots belong to the onset or the rime. Critics of the OR model have also noted OR model's overgeneration of possible types of compensatory lengthening (Hayes 1989), whereas in the μ-model, compensatory lengthening applies only to the loss of moraic entities. As far as we are able to tell, the force of argument of the μ-model is so strong that proponents of the OR model must concede to the reality of moras, even if one wishes to retain the use of onsets and rimes.

2.3 Melodic content and temporal ordering

As mentioned earlier, the OR model has skeletal segments that are filled with featural melodies (i.e. distinctive features). In contrast, the μ-model does away

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3. We cannot resist noting that the μ-model will be unable to explain away onset-coda asymmetries especially in languages where codas are non-moraic. In OR models, the onset would asymmetrically c-command the coda.

4. As in Hindi (Pandey 1989), Estonian, some dialects of Arabic, St Lawrence Island Yupik (all in Hayes 1995), and Punjabi (Dhillon 2007). Even with a three-way distinction for weight, the μ-model is superior to the OR model.

5. First in Jakobson et al. (1951), adopted in SPE (Chomsky & Halle 1968) and continues with minor changes to autosegmental phonology (Goldsmith 1976).

with skeletal slots and have melodies directly associated with the moras via the root nodes of the feature geometry structure. The OR model has the advantage of mirroring temporal phonetic reality, that syllables with more segments do take a longer time to articulate. The μ-model does not capture this fact[6] as it makes only as many distinctions as there are moras for a given syllable. Both OR and μ-models must encode linear ordering of segments/root nodes. For affricates and aspirates, the OR model may assume that a segmental slot X is comprised of two root nodes that sequence the plosive and the fricative. For the μ-model, one will have to sequence the [−continuant][+continuant] features within the same root node, but we are not sure how to do that elegantly when given an aspirated affricate that may not be homorganic (e.g. [k͡pʰ]). Our inabilities lead us to believe that melodies must associate with segments, contrary to stricter proponents of the μ-model.

2.4 Interim thoughts

The preceding paragraphs have outlined the relative strengths of two competing models. In the process, a two-dimensional picture of the syllable emerges: the dimension of rhythm and prosody that the μ-model excels in, and the dimension of configuration and melodies that the OR model does well. At this point, one is confronted with an iconoclastic thought: When construed in terms of a moraic dimension versus a constituency dimension, the idea of segments appears to belong more to the former (the temporal, rhythmic moraic dimension) and the idea of melodies appear to belong more to the latter (the configurational melody dimension). This is the basis of the segment-melody complex proposed in Srinivas (2016), to which we shall return in § 4. We next turn to the Chinese syllable difficulties that we hope to address.

3. Two Chinese syllable difficulties

3.1 The status of the medial glide

The essence of the medial glide problem is thus: given a CGV(X) syllable, what is the membership status of G? The issue is mostly discussed within an OR model, where the G is ambivalent in its membership to the onset or the rime. In terms of the μ-model, the question could be reframed as whether or not the G is moraic.

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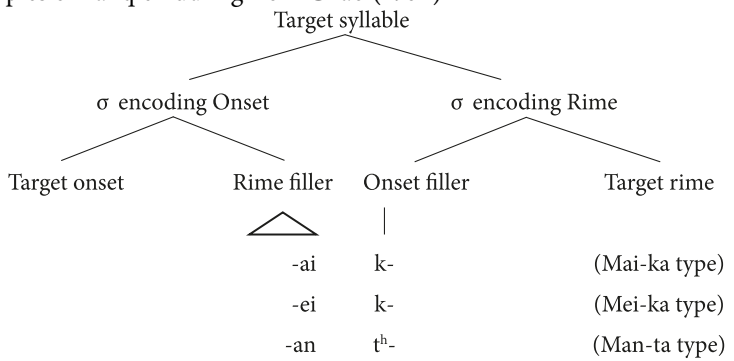
6. Since this is phonetic, the phonologist might argue that the temporal length that comes from there being more segments/root nodes is irrelevant to the speaker's I-Grammar.

Generally, the various stances that have been adopted are that (i) C^G is a single segment/unit, (ii) CG is consonant cluster onset, (iii) G is sister of C and V(X), (iv) G c-commands the constituent with V(X) while in turn being c-commanded by C, and (v) GV forms a constituent to the exclusion of X. For a good summary and review of the various positions see Duanmu (2007: 25–33; 2009: 77).[7]

Not all Chinese languages face this challenge. In Standard Cantonese, for example, syllables are maximally CVX, with no glide to complicate things.[8] By the same logic, it would be unwise to think of the glide problem as having a unique solution to all Chinese languages that have a medial glide (Wee 2011), although that has not stopped some from trying. Unsurprisingly, Pan (2006) and Sun (2006), in their attempts to find a unified solution for all Chinese languages, show how the range of evidence contradicts one another. However, even within a single language, let's say Standard Chinese, the issue is not easily resolved. Among the three Standard Chinese (Beijing)-based ludlings reported in Chao (1931), one finds the medial glide often encoded in the syllable representing the target onset as well as that representing the target rime.

(1) Examples of Fanqie Ludling from Chao (1931)



Target σ		Encoded Onset	Encoded Rime	Ludling type
a. [ɕyan] 'announce'	→	**ɕ**y**ɛ**	t**ɕyan**	Mai-ka
b. [xuɔ] 'alive'	→	**x**u**ei**	k**uɔ**	Mei-ka
c. [liɛn] 'face'	→	**li**ɛ**n**	t**ʰiɛn**	Man-t**ʰa**

7. Following Duanmu (2009: 77), (i) is supported in Cheung (1986), Duanmu (1990), Ao (1992) and Wang (1993); (ii) in Bao (1990: 328) and Fu (1990, echoed also in Cai's 2005 of Standard Chinese ludlings); (iii) in Chao (1934), Li (1983), Lin (1989), and Bao (1990); (iv) in Robert Cheng (1966), Chin-chuan Cheng (1973), Wang (1955), Lin (1989), and Baxter (1992); and (v) in Bao (1990: 342) and Goh (2000).

8. The onset [k^w] has been demonstrated phonetically to be a labialized [k] and hence not a case of there being a glide (Zee 1991). Also, see Cheung (1986).

The three ludlings in (1) can be understood through the template, where two syllables are used to encode the target. The first syllable retains the target onset while employing a rime filler; the second retains the target rime while employing an onset filler. The three ludlings are named after how they would each encode the syllable [ma] 'mother'. With a syllable like [ma] where there are no medial glides, the [m] and [a] would split into their respective encoding syllables. This is the modus operandi of *fanqie* that has been in used in classical Chinese phonology since as early as the 6th century (Goh 2015). However, as we can see from the selected examples in (1a–c), the cases where there are medial glides are ambivalent as the glides appear in both encoding syllables (see also Hsieh 2018 for a very nuanced phonetic study).

Given how arguments and evidence have pointed both ways, perhaps, it is incorrect to try force the issue on the membership of the medial glide, and one should recognize a systematic cause for its ambivalence.

3.2 Tonelessness and weight conundrum

Tonelessness presents the second difficulty in the reckoning of the Chinese syllable. In this aspect, there too is variation across the various Chinese languages. Among the Mandarin languages such as Standard Chinese, toneless syllables are necessarily suffixed to a stem and have a shorter duration. They are by no means simpler than fully-toned syllables in terms of the number of segments, as may be evidenced by patterns of reduplication or by tone-reduction (Lin & Yan 1980; Lin 1985; Cao 1995), e.g. *nǎi nai* [nai] 'granny', *dé xing* [ɕɪŋ] 'appearance (derogatory)'. These syllables are said to be toneless because their pitch values vary widely and often in relation to the tone value of the preceding syllables. Wang (2002)[9] describes, for example, that the toneless syllable is low[10] when following all Standard Chinese syllables except those of the third tone (T3) where the toneless syllable would be high. Lin & Yan (1980) describe the neutral tone as a full falling tone when preceded by a high tone, but is a high flat tone when preceded by a low tone.

In other Chinese languages, tonelessness may again be somewhat different. In Urumqi Mandarin, Wang (2002) notes that toneless syllables are not shorter in length, but have predictable tone values that are falling or rising depending also on the tone of the preceding syllables. Chen & Xu (2006), however, find the neutral tone in Standard Chinese to be a stable and static mid tone that is approached

9. See also Li (2004) for a more comprehensive survey of tonelessness across Chinese languages.

10. Albeit not very low.

from the preceding syllable's tonal offset (in partial agreement with Cao (1995), who also believed that the onset pitch of the neutral-toned syllable is influenced by the preceding syllable).

In Wu dialects (Chen 2000, among others, and for an updated treatment, see Yan 2018), syllables are rendered toneless when non-initial, but will inherit the tones of the initial syllable via Mende-style (Leben 1973) spreading.[11] In Southern Min languages, tonelessness is evidenced through the non-participation of sandhi, i.e. they do not trigger tone sandhi. Thus, toneless syllables in Southern Min appear almost indistinguishable from fully-toned ones in terms of duration and rhyme complexity (see Wee 2020; forthcoming).

In highlighting the differences of tonelessness across the Chinese languages, we hope that it is clear that we are not making a simplistic conflation of these phenomenon. The reader is probably aware of different names that have been attributed to the different types of tonelessness, such as referring to the Standard Chinese type as neutral tone, while the Bantu-style type of tone spreading in Wu as tonal neutralization. However, underlying these different names is the common observation of tone neutrality (either by dissociation or base-generated as toneless).

Again, focusing only on Standard Chinese, the fact that toneless syllables do not occur in isolation suggests that they do not form minimal prosodic words. This is substantiated by the fact that they are shorter in duration, despite the fullness of their syllable structure, i.e. being possible CGVC (consider for example *niáng niang* [niɑŋ] 'the ladyship'). In moraic terms, toneless syllables in Standard Chinese must therefore be monomoraic, and hence unable to make a binary foot. To the best of our knowledge, it would be uncanny to claim that the reduplicant here does not rhyme with the base, which means one must consider the syllable also in terms of identical rimes even when there is non-identity of moraicity.

4. The segment-melody complex

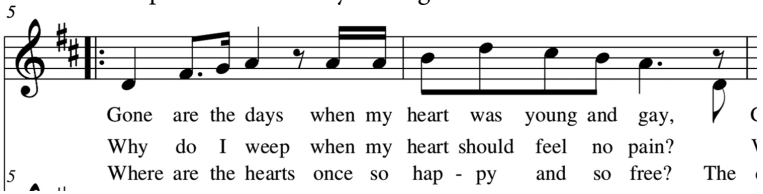
The basic idea of the segment-melody complex is encapsulated in (2).

(2) The segment-melody complex

11. More aptly, Kukuya (Hyman 1987).

The schema in (2) indicates that a segment and the associated melodies (i.e. distinct features) belong to two different dimensions. The prosodic tier is where rhythm, time, and other entities of a prosodic nature are located. These are largely contentless in the same way a beat in music is just a placeholder for notes. The music analogy extends to the featural melodic tier where phonetic/phonological content are fleshed out. Structurally, both tiers are distinct, and mismatches are allowed. To understand this, consider first an example in music, where the phrasing of the melody is distinct from the prosodic meter of the beats and rhythms.

(3) Musical example of beat-melody misalignment

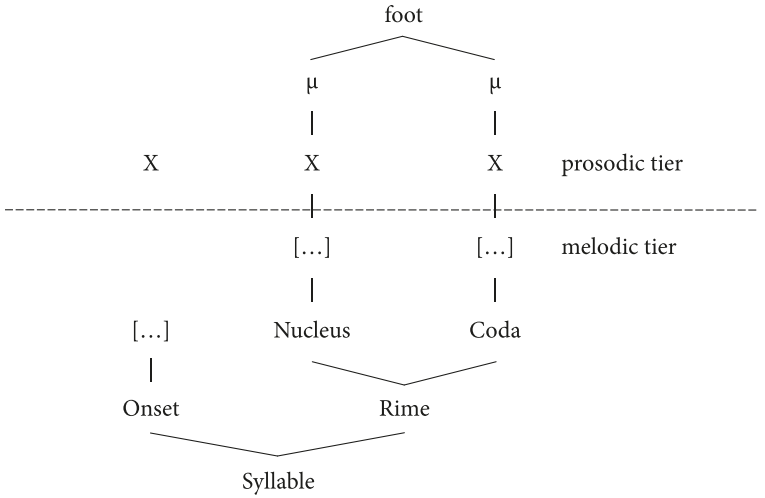


Stephen C. Foster (1860) *Old Black Joe*, free-of-copyright image, https://musopen.org/music/41776-old-black-joe/

In (3), we can see that the first phrase *Gone are the days* ends before the end of the first measure. The second phrase … *when my* … starts before the second measure. This is reflected not just in the lyrics, but more importantly the melody, which is broken by a pause. The tempo and beat, however, goes on unhindered with four beats to each measure and accents in every odd-numbered beat. The segment-melody complex is phonologically analogous.

While this idea is not revolutionary, it is not one that has been seriously considered by phonologists in their studies of the syllable. Still using (3), it is clear that even within the first musical phrase, there is internal structure: *Gone…are the…days* (not the syntax, but the tune). This melody structure is not the same as the | X x X x | rhythmic structure. The sizes of the Xs show how the beats are organized into trochaic pairs such that the first pair is more heavily accented than the second. Following this analogy, a logically coherent way to organize the syllable would be as in (4).

(4) Projections of the segment-melody complex (Srinivas 2016)



In (4), segments, moras, and feet, all related to timing and prosody, are in the same dimension. In the melody dimension, the phonological features are organized into melodic constituencies of onsets and rhymes. This model upsets the conventional understanding that either moras or syllables may form feet. It takes a more restrictive position that syllables offer nothing more than constituencies of the phonetic melodies and it is the moras that form feet. The advantage of such a view is that it avoids having to stipulate if a language is footed by syllables or moras. Languages that appear to be footed by syllables can be captured by assuming that only the most sonorant melody in the melodic tier is moraic. This is a more coherent approach because it allows for a typology of predictions: (i) that both nucleus and coda are moraic (i.e. mapped to a mora in the prosodic tier); (ii) only the nucleus is moraic; (iii) onset, nucleus and coda are moraic. All these predictions are borne out. Type (i) is found in languages like English where heavy syllables are minimal (prosodic) words. Type (ii) is attested in languages like Bidyara, Diyari, Mohawk, Pitta-Pitta (Hayes 1995: 88), Bangla, Punjabi, and Tamil (Vijayakrishnan 2002) where a minimal prosodic word must be two syllables. The onset moraicity[12] of type (iii) is found in Pattani Malay (Topintzi 2008; also 2010: 11, citing Yupho 1989) where [buwɔ́h] 'fruit' and [bːúwɔh] 'to bear fruit' contrast in stress assignment corresponding to gemination of the onset. Kelly (2004) demonstrates this to be relevant even in English, as stress falls more readily on the first syllable of a nonce word like *brontoon* than on the second, but with

12. Most notably, see Hsieh (2017) who offers not only a crystallized summary of works related to onset moraicity, but argues also that the medial glide in Standard Chinese might yield to such an understanding.

bontoon, then stress falls more readily on the second syllable. Hirsch (2014) suggests the same with *keefoos* and *keefloos*, noting that stressing the first syllable is harder in the latter. Tamilian English exhibits similar stress shifts that appear to be onset sensitive (Vijayakrishnan 1978; cited in Srinivas 2012: 59). In Tamilian English, words like *insect* [in.ˈsekt], *image* [i.ˈme:dʒ] and *energy* [e.ˈnar.dʒi] have a heavy second syllable, where they are stressed. The given words also have a variant with a word-initial initial glide i.e. [ˈjin.sekt], [ˈji.me:dʒ]. [ˈje.nar.dʒi]. When the glide is inserted, however, stress shifts to the word-initial syllable.[13]

Details of the model aside, the ensuing paragraphs turn to the treatment of the medial glide in Chinese and the issue of tonelessness.

4.1 The ambivalence of the medial glide

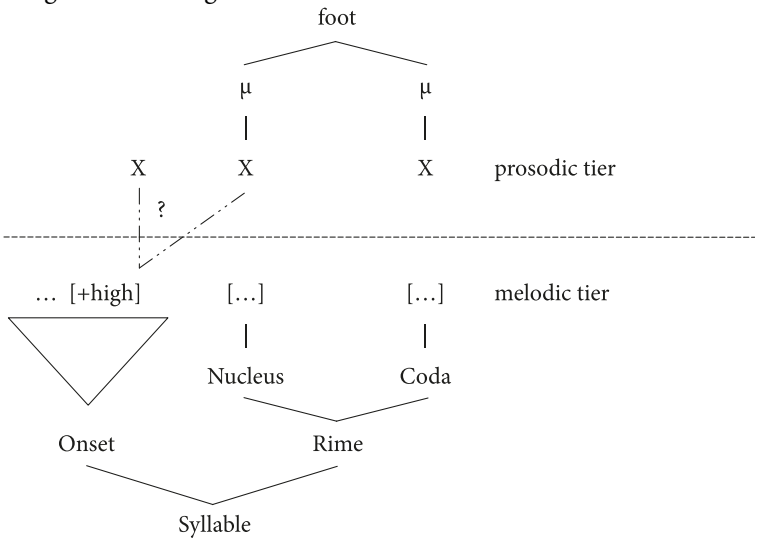
Recall that the issue of the medial glide is one of ambivalence in (i) constituency membership and (ii) moraicity. The problem of constituency is itself dual layered. The first and simpler one is that different Chineses treat the glide differently. The solution is straightforward enough if we simply recognize that different Chineses may have different models of the syllable. Some may tolerate CG onsets, others may not, and yet others may have a larger consonantal inventory to include gesturally complex C^G consonants. Since there is no *a priori* reason to believe that different speech communities should have the same phonotatics even if they speak languages that have a common ancestry, this is a non-issue. The same may be said of ambivalence in moraicity of G. The real problem is when one has conflicting evidence within same speech community, where, on the one hand, G exhibits moraicity and, on the other, shows solidarity with the onset C.

The dual dimensionality of the segment-melody complex resolves this rather easily, as what is moraic is not necessarily what is part of the rime. In fact, two types of ambivalence would be theoretically predicted, (5).

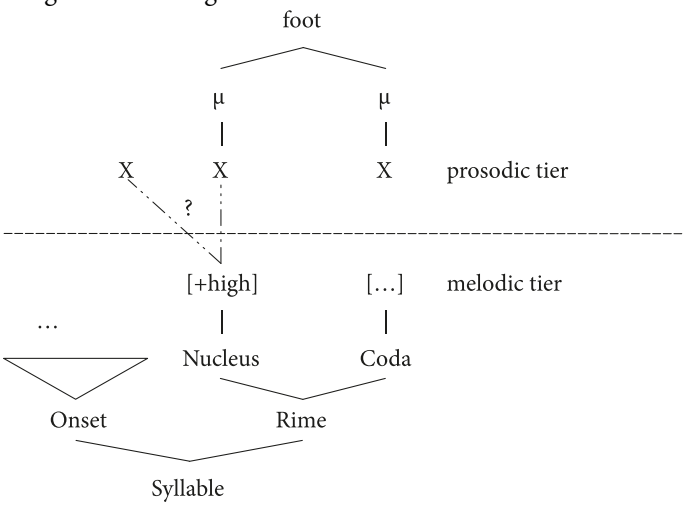
13. Thanks to Srinivas for this piece of corroborative information.

(5) Two-types of ambivalence of the medial glide

a. Weighted or unweighted onset



b. Weighted or unweighted nucleus



In (5), the glide is represented as a melody that has the feature [+high],[14] typifying the glide forms [j, w, ɥ] (or [i, u y] in Standard Chinese if construed as vocalic).

14. A reviewer points out that in languages such as Yanshi 偃師, there is a larger inventory of medial including -j-, -w-, and -ɥ- as well as -l- or -r- or -ɻ-, e.g. 幫兒 [pɻar] 'the white stem part of cabbage leaf'. This does not pose a problem for the model since not all medials are glides. Depending on the actual language data, the consonantal approximants may be in the onset. If

That glide may be part of the onset (5a) or the rime (5b). Even in (5a), it is possible that the glide is unweighted and therefore behaves unambiguously as part of the onset, or it may be weighted (as demonstrated to be fully possible by Hsieh 2017; 2018). If weighted, then the evidence might be interpreted, possibly erroneously, as part of the rime because the prevalent conceptualization is that only rime entities may be weighted.

The mirror situation is that of (5b), where the glide is part of the rime, and enters into the rhyming scheme or into the formation of ludling. Again, it may be weighted or unweighted. If unweighted, the situation becomes ambiguous again for those who believe that all elements in the nucleus must be weighted.

So, which exactly is the situation of Chinese? As noted before, desires for such sweeping solutions need to be held in check. There is no *a priori* reason to believe that each individual speaker may not have a different grammar. Wee (2011) reports that this may indeed be the case. Among Malaysian Mandarin speakers, for example, *duan-guan* is judged to rhyme more strongly than *guan-gan or duan-gan*. Among Singaporean speakers however, there are some who do not consider *guan-gan* and *duan-gan* to rhyme at all. The models in (5) predict four types of speakers for a given syllable, say *tiao* in Standard Chinese: *ti-*, *ti*$^{\mu}$*-*, *-iao*, and *i*$^{\mu}$*ao*. Further, one might expect the possibility of speakers who treat *tiao* and *xiao* differently based on differences in homorganicity between the consonant *t-* and *x-* with the glide. The latter *x-* [ɕ] shares the feature [high] with the glide, and may be indicative of closer proximity as part of the same constituent. This typology of possibilities is not predicted by any theory of the syllable that fails to incorporate and separate prosody with the constituency of melodies.

4.2 Tonelessness and prosody

In Standard Chinese, toneless syllables are uncontroversially light (Wang 2002; Li 2004; Wee 2004: 176–180; Duanmu 2007: 140–143, among others). This is evidenced phonetically by their shorter duration and lighter intensity, and also morpho-phonologically by their non-participation in tone sandhi and their restricted distribution in non-initial positions.[15] Recall from § 3.2, that the conun-

demonstrably weighted, that could also be accommodated, recall discussion in the opening of § 4.

15. A reviewer also kindly pointed out that in Standard Chinese, the neutral tone triggers duration compensation by extending the nucleus of the first syllable in a disyllabic string, indicative of trochaicity in such cases. Within our framework, this could be captured by the leftward migration of the moras sourced from the reduced syllable. However, investigations since 1980 to present have not shown such compensatory lengthening of the pre-neutral tone syllable to

drum is with how complex syllables like CGVX (recall *niáng niang* [niɑŋ] 'ladyship', and also *qiū tian* [tʰien] 'autumn', *kàn kan* [kʰan] 'take a look', among numerous examples since tone neutralization is productive in Standard Chinese) can be light. Following the results of Chen and Xu's (2006) study, at the level of the prosody, there must therefore only be one mora for the neutral-toned syllables in Standard Chinese. For those who subscribed to their analysis that there is a tone value for the neutral tone (i.e. mid) this can be accounted for either by having the mora receive a default pitch, or by stipulating that the mora has a tone feature. This distinction is tangential to the concerns of this paper.

What is important is that these toneless syllables are capable of entering into the rhyming scheme,[16] which means there is something about the melody makeup and organization that must be relevant to the phonology. The model in (5) offers a straightforward solution in that the lightness of the syllable in terms of how many moras there are does not impact on the structural makeup of the syllable. Further, this approach offers a natural explanation as to why the toneless Standard Chinese syllable is not a minimal prosodic word (because it is not bimoraic and therefore not a foot), even when the segmental melodies can be quite complex. It leaves intact the monosyllable that is bimoraic would form a foot and is therefore a minimal prosodic word.

There is a substantial group among Chinese linguists, most notably represented by Feng (1997, 1998, 2001 and subsequent works), who argue for the Standard Chinese word to be minimally disyllabic. Despite the different justifications that Feng and his followers offer, it remains true that many monosyllables are minimal prosodic words with the exception of the toneless ones. These monosyllabic forms are treated as "degenerate" under the assumption of disyllabic minimality, in effect committing Standard Chinese to be the "syllabic trochee" type (see Hayes 1995: 89 for languages with degenerate feet). This approach appears contrived given that tone stability is on the right under sandhi and that trochaicity is largely clear only with toneless syllable endings (morphosyntactically derived

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apply in Standard Chinese. Notably Lin & Yan (1980; 1990) and Cao (1986) have shown that syllables preceding a neutral tone may have varying lengths before and after the following syllable has neutralized, although Cao (1995) notes that third tone syllables might lengthen if the following syllable is neutralized. Corpus research in Feng et al. (2001) and Deng et al. (2004) suggests that lengthening may have more to do with syntactic boundaries than with tone neutralization.

16. Consider for example the proverb 捡了芝麻 *jiǎn-le zhīma* [ma], 丢了西瓜 *diū-le xīgua* [kua] 'having picked-up the sesame seeds, but losing the watermelons (penny-wise pound-foolish)'. Toneless [ma] and [gua] rhyme. Naturally, there are speakers for whom the relevant syllables are not read in neutral tone, but that does not change the fact that there are also those who do.

by reduction, reduplication or limited cases of suffixations). Wu languages would fit the description of syllabic trochees better than Standard Chinese. Although there are also monosyllabic words in Wu, disyllabic or longer words necessarily involve the displacement of the tones of non-initial syllables by the tonal features of the initial syllable. The toneless syllables in Wu cannot occur as isolates, and are bound. In contrast, most di-/polysyllabic words in Standard Chinese allow each syllable to be minimal prosodic words.

Among the Southern Min languages where tone stability under sandhi is also on the right, tonelessness is not characterized by lightness of the syllable, but solely on how they do not trigger tone sandhi (again, see Wee (2021) and Liang (2007) for a cross-dialectal perspective). In Chaozhou, for example, the tone value [21] may either trigger or not trigger sandhi, exemplified in (6).

(6) Sandhi-triggering versus non-sandhi triggering [21] in Chaozhou

a. Sandhi-triggering [21]

i.	$k^{h}iŋ^{24\leftarrow 33}$ $t^{h}iʔ^{21}$	'aluminium' (p. 32)
ii.	$nãʔ^{31\leftarrow 33}$ sap^{21}	'trash' (p. 35)
iii.	$sĩã^{33\leftarrow 55}$ $seʔ^{21}$	'sound' (p. 39)
iv.	$mũã^{213\leftarrow 55}$ $ts^{h}iaʔ^{21}$	'sparrow/mahjong' (p. 63)
v.	$bat^{21\leftarrow 44}$ sak^{21}	'wood louse' (p. 79)
vi.	$k^{h}a^{24\leftarrow 33}$ $k^{h}iʔ^{21}$	'hoof' (p. 84)
vii.	$tɯ^{24\leftarrow 33}$ $hueʔ^{21}$	'pig's blood' (p. 131)
viii.	$p^{h}ue^{53\leftarrow 213}$ $kaʔ^{21}$	'side dish/condiment'(p. 134)
ix.	$ka^{53\leftarrow 213}$ $siʔ^{21}$	'classroom' (p. 232)
x.	$iŋ^{213\leftarrow 55}$ pik^{21}	'pencil' (p. 236)

b. Non-sandhi triggering [21]

i.	$tsõĩ^{55}$ $nĩ^{21}$	'year before last' (p. 18) (cf. $mẽ^{213\leftarrow 55}$ $nĩ^{55}$ 'next year' (p. 16))
ii.	$tua^{12\leftarrow 11}$ $tsõĩ^{55}$ $nĩ^{21}$	'year before year before last' (p. 18)
iii.	$tsõĩ^{55}$ zik^{21}	'day before yesterday' (p. 22) (cf. $tsĩẽ^{31\leftarrow 35}$ zik^{44} 'day before yesterday' (p. 22))
iv.	zik^{44} kua^{21}	'daytime' (p. 23)
v.	$siu^{13\leftarrow 53}$ kua^{53} ai^{21}	'widow' (p. 280)
vi.	$kĩ^{55}$ $t^{h}au^{21}$	'at the side' (p. 320)
vii.	mak^{44} $siap^{21}$	'sleepy' (p. 528)
viii.	$i^{4}/uŋ^{53}/naŋ^{53}/niŋ^{53}$ kai^{21}	'his, mine, ours theirs' (p. 554–555)
ix.	i^{4} $naŋ^{21}$ kai^{21}	'theirs' (p. 556)
x.	$tsi^{53}/hɯ^{53}$ kai^{21}	'this, that' (p. 557)

xi. tsi^{53}/hɯ^{53} tsoʔ^{21} 'these, those' (p. 558)
xii. hɯ^{53} koʔ^{21} 'there' (p. 559)
(Peking University (1995), reported in Wee (2020))

The main observation here is that the non-sandhi-triggering [21] must be phonologically toneless. In fact, Peking University (1995: 41) explicitly listed [21] both as part of the tonal inventory of Chaozhou while also noting that the Chaozhou 'light' tone is [21].

It is unclear whether the toneless [21] syllables in (6b) are themselves minimal prosodic words. Intuitions from speakers of Chaozhou interviewed lean towards an affirmative judgement. When these syllables are offered in a frame, "In the word AB, how is B written?"[17] the syllable B's tone appears to be consistent – appears to be the same – when part of the word AB and when isolated. Direct solicitation of intuition from speakers as to the status of B as word also produce affirmative responses. The kind of tonelessness seen in Chaozhou is rarely mentioned in the discussion of tonelessness, which suggests that they are as different from the kind found in Standard Chinese.

In the model given in (5), Chaozhou-type languages can be captured by the maintenance of bimoraicity – only the tone features are absent – while the Standard Chinese-type can be construed in terms of monomoraicity. This avoids the issue of massive degenerate footing required by the disyllabic minimality hypothesis. As for there generally being more disyllabic words than monosyllabic ones in Standard Chinese, that is hardly an argument for disyllabic minimality at all. English has more disyllabic words than monosyllabic ones as well, and presumably a similar case can be made for there being more polysyllabic words than disyllabic ones.

5. Moraicity versus syllabicity

If the model presented in §4 is correct, then discussions on any of the Chinese languages will require a more nuanced set of data. It would specifically require us to identify a set of informants with whom experiments of rhyming, rhythm and even play language manipulation must be done together with phonetic measurements. A more effective way to test the validity of the segment-melody complex and its corollary model may be to spell out their predictions to see which are borne out. This is the main concern of this section. The main prediction is that

17. The frame would be "AB kai^{21} B tso^{11} mue?^{21} sia^{53}?". E.g. "*zik*^{44} *kua*^{21}kai^{21} *kua*^{21} tso^{11} mue?^{21} sia^{53}? (In the word *zik*^{44} *kua*^{21}, how is *kua*^{21} written?)"

moraicity is distinct from syllabicity in (4). One would therefore expect (i) syllables that are not moraic, (ii) effects of mediation from the skeletal slots that link the moras to the root nodes of the melodies, and (iii) moraic constituents that do not form syllables.

The first case of syllables that are not moraic is evidenced by the types of tonelessness and discussed in § 5.1.[18] Effects of the skeletal slots that mediate the mora and the melodic root node will be discussed in § 5.2. Finally, moraic items that are not syllabic will be discussed in § 5.3.

5.1 Syllables of varying moraicity

Assuming the mora to be the tone bearing unit (TBU), tonelessness may come in three flavors. First is the option of moraic retention, where the effect of tonelessness is the result of simple deleting tone features while leaving intact the morae (e.g. Chaozhou). Second is the option of partial moraic deletion where one of the two moras is removed, leaving intact either all or some tone features. Finally, the third option is of full moraic deletion, which necessarily also deletes all tone features by stray erasure.

Full moraic retention has been discussed in Chaozhou earlier, so warrants no further discussion. The other two will need some elaboration, both of which are available in Standard Chinese. Although largely unnoticed, the so-called toneless syllables in Standard Chinese come in two varieties: one of which triggers tone sandhi and appears to preserve a stronger similarity with its underlying unreduced form (e.g. (7e) below); the other appears to be more like a default pitch (e.g. (7a–c) below).

(7) a. Reduplication

i.	*ge*^{55}*.ge*^{0}	'(elder) brother'
ii.	*niang*^{35}*.niang*^{0}	'her ladyship'
iii.	*jie*^{21}*.jie*^{0}	'(elder) sister'
iv.	*di*^{51}*.di*^{0}	'(younger) brother'

b. Genitive suffix *-de*

i.	*zhang*^{55}*san*^{55}*.de*^{0}	'Zhang San's'
ii.	*huo*^{35}*.de*^{0}	'alive'
iii.	*si*^{21}*.de*^{0}	'dead'
iv.	*li*^{21}*si*^{51}*. de*^{0}	'Lisi's'

18. See also Srinivas (2016: 132–134) for possibility of non-moraic syllables in extrametrical positions.

c. Adverbial suffix -*de*[19]
   i. *qing*^{55}*qing*^{55}*.de*^{0} 'gently'
   ii. *huo*^{35}*huo*^{35}*.de*^{0} 'alive'
   iii. *mei*^{35}*mei*^{21}*.de*^{0} 'beautifully'
   iv. *zhong*^{51}*zhong*^{51}*.de*^{0} 'in a heavy manner'

d. Adverbial marker –*de*
   i. *feiji fei*^{55} *de*^{0} *gao* 'planes fly high'
   ii. *wo pao*^{21} *de*^{0} *kuai* 'I run fast'
   iii. *ta tiao*^{51} *de*^{0} *yuan* 'he jumps far'

e. Morphological reduced forms
   i. *gao*^{55}*.xing*$^{51\rightarrow 0}$ 'happy'
   ii. *lou*^{35}*.shang*$^{51\rightarrow 0}$ 'upstairs'
   iii. *zhao*^{51}*.gu*$^{51\rightarrow 0}$ 'take care of'
   iv. *da*^{14}*.shou*$^{214\rightarrow 0}$ 'bouncer'[20]
   v. *sheng*^{51}*.ming*$^{35\rightarrow 0}$ 'wise'[21]
   vi. *cong*^{55}*.ming*$^{35\rightarrow 0}$ 'intelligent'

Most literature on the light tone in Standard Chinese today do not distinguish the neutral tones given in the five different morphosyntactic operations in (7), and assigns them with the convenient tone value 0, but see discussion in § 3.2. It should further be noted that the reduplications given in (7a) are nominal types, although verbal and adverbial reduplication are also possible. In verbal reduplication, there is the option of tone reduction or preservation for the reduplicant, and verbal reduplication would trigger tone sandhi if the source syllable carries the third tone. Adverbial reduplication is seen in (7c), and again the reduplicant may undergo some kind tonal change. Verbal and adverbial reduplications are therefore potentially reduplications that include tone than the type shown in (7a), where reduplication is probably purely segmental. These complications are tan-

19. Particularly in contexts where these adverbials describe a situation. E.g.

Jǐ tiān méi hē shǔi, huó huó de ké sǐ le.
few day NEG drink water, *huó huó de* thirst die ASP.
'A few days without drinking water, leads to death from thirst.'

20. There is some debate on how exactly to notate the tone of *da* which was underlyingly /214/ before it sandhied into a rising contour. Our choice here merely reflects the fact that the derived rising has a lower F0 profile than the underived one (e.g. Xu 1997; Yin 2002).

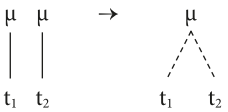
21. A reviewer appears unconvinced of the authenticity, but it is in fact reported in corpora such as Zhang (1977). Nonetheless, there seems to be some words that have fallen into disuse and may not come easily to mind.

gential to the paper as our concerns do not dwell on the mechanisms triggering tone neutralization, but on the phonological quality of syllables that carry the neutral tone.

In our study, we found that there are native speakers for whom the neutral tone for (7a–c) is different than those for (7d–e), even though there are others who cannot distinguish them.[22] Those who find (7a–c) different from (7d–e), intuit that neutral tones in (7d–e) appear more contrastive as if the underlying tones are not fully lost. They give the impression of (partial) lenition. In contrast (7a–c), appear to have been base-generated as phonologically toneless. If true, then the kind of tonelessness in (7a–c) would correspond to (8a) and the tonelessness of (7d–e) to (8b), exactly as predicted by our theory.

(8) a. Full moraic deletion
∅
(t)

b. Partial moraic deletion



To be precise the operations in (7a–c) may not involve reduction at all, as given in (8a). The parenthetic (t) in (8a) indicates the possibility of a tonal target as argued for in Chen & Xu (2006) or in Cao (1995). If syllables are generated without moras (as allowed in the model in (4)), then we can expect syllables that are weightless. Weightlessness in absolute terms may be hard to qualify (but see Hyman (1985: 59); Levin (1985: 295–296); Kager (1990); and Gordon (1999: 9; 2002) for the potential non-moraicity of central/reduced vowels), but here we can see an argument for them via contrast with (8b).

In (8b), it is hard to ascertain – and this may not be the place – how the tone features coalesce (or delete) for the various scenarios in (7d–e). However, there is some evidence that (7d–e) are different from (7a–c). First of all, allophonic variation between the underlying tones and the neutral tones are observed in (7d–e). In (7d) for example, all the *de*-s can be pronounced as a distinct rising tone despite its consistent shorter duration than the preceding syllable. As a verb, this same *de* has a tone value [35]. Similarly in (7e), the syllables that are underlyingly [51] can be articulated with a distinct falling pitch contour despite their shortness in duration. That expectation for a rising contour as an allophonic variation for

22. It is unclear to us if precedent studies employed speakers who all belonged to the group that does not intuit any difference in the neutral tones of (7a–c) and (7d–e), or if the studies had collapsed the two groups of speakers.

in (7ev) is also borne out. (7eiv) comes out as a mildly falling very low tone that presumably stems from its [21(4)] source as well. Only (7evi) is unexpected, with the *ming* appearing with a falling contour. However, even that is clearly unlike those of (7a–c). Second, albeit more weakly, is the issue of tone sandhi. In (7e), the famous Standard Chinese third tone sandhi applies, as seen in (7eiii). This is harder to observe in non-sandhi tonal collocations, as in (7d). For the (7a) type, third tone sandhi does not apply.

Finally, the theory makes an acoustic prediction that there should be a three-way contrast for syllable length differentiating fully toned syllables that are bimoraic, from neutral-toned ones that are monomoraic and those that are non-moraic. A fuller study on this acoustic prediction would require a different paper, although a preliminary one suggests optimism.

(9) Duration measurements of the toneless syllables[23]

		Duration	**Std Dev**
Toned syllables	Control	0.350s	0.048
Neutral-toned syllables	Genitive *de* 的	0.196s	0.044
	Adverbial suffix *de* 地	0.140s	0.038
	Adverbial marker *de* 得	0.266s	0.051
	Non-tonal reduplication (e.g. 哥哥)	0.252s	0.038

The data in (9) is taken from the careful speech articulations of a 40-year-old native male speaker of Putonghua. In this simplistic pilot, the subject articulated the words in (7) three times from which we take measurements using Praat. Following usual practice, syllable length is determined by identifying the syllable boundaries using a combination of the wide-band spectrograms and waveforms. Careful speech is used so that any differences would be evident. We can see clearly that the control syllables which have full tones are longest. All others have shorter durations, presumably by moraic deletion. Genitive *de* and adverbial suffix *de* are shortest. Adverbial marker *de* and partial reduplication have neutral tone syllables not quite as long as the fully-toned syllables but are nonetheless longer than the genitive and adverbial suffix *de*-s. The three-way durational contrasts are arguably the reflection of the three-way distinction of weight (bi-, mono-, and non-moraic) which is predicted by our model of the syllable.

23. Thanks to the HKBU Phonology Lab for help with this experiment. We wish to note that we did also find speakers for whom the reduction is consistent so that there is only a two-way contrast for syllable weight/length. This, however, does not diminish the fact that there are speakers such as the one presented in (9), which would require explanation.

5.2 Mediation effects of the skeletal slots

The model in (4) entails that moras and melodies are mediated by skeletal segmental slots. This predicts that when skeletal tier slots are deleted, the accompanying melodies would also be loss. In contrast, traditional moraic models without X slots map syllable (σ) and mora (μ) directly to root nodes that constitute the featural melodies. When root nodes are unmapped, it remains possible for the features to serve as coarticulations for adjacent melodies. This subtle difference is seen in the Formosan language Squliq Atayal which exhibits vowel deletion of the stem when followed by suffixes such as *-an* and *-un*. This is exemplified below with *-an* in comparison with cases of prefixation in (10).

(10) Antepenultimate vowel reduction in Squliq Atayal

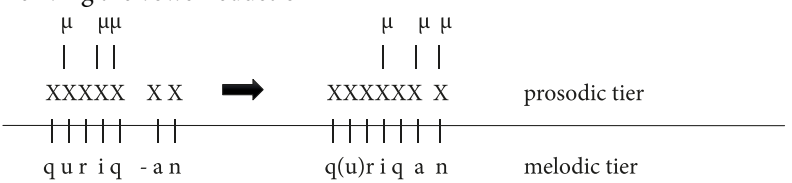
	Penult V	Stem	Prefix /m-/	Suffix /–an/	gloss
a.	/i/	biruʔ	miruʔ	bruan	'write'
b.	/e/	tehuk		thkan	'arrive'
c.	/u/	quriq	mquriq	qriqan	'steal'
d.	/o/	hoqil	mhoqil	hqilan	'die'
e.	/a/	abiʔ	mʔabiʔ	ʔbian	'sleep'

(Huang (2018), citing Egerod (1965))

As may be seen in (10), prefixation does not trigger vowel reduction, although phonotactic constraints might coalesce /m-b/ to become a single [m] in (10a) or allow word-initial [ʔ] to surface in (10e). What concerns us here is the suffixation of *-an* is accompanied by the loss of the antepenultimate vowel that generates consonant clusters. Consonant clusters are marked in Squliq as may be seen from the general lack of such clusters in the stems. The puzzle with *-an* suffixation in Squliq is the unexpected creation of structures that are more marked.

This situation finds a rather natural explanation with models like (4) where moraic information and melodic information are separated. The leading idea here would be that the suffix *-an* supplies melodic information without any accompanying mora. The concatenation thus leaves one with the original number of moras and melodies of the stem.

(11) Deriving the vowel reduction

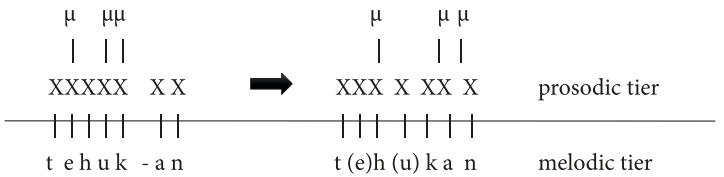


Exemplified in (11) is how a simple matter of remapping the segments with the mora would yield the expected vowel reduction resulting in consonant clusters that serve as onsets. The loss of the antepenultimate vowel can be explained by its violation of sonority wellformedness of onsets.[24]

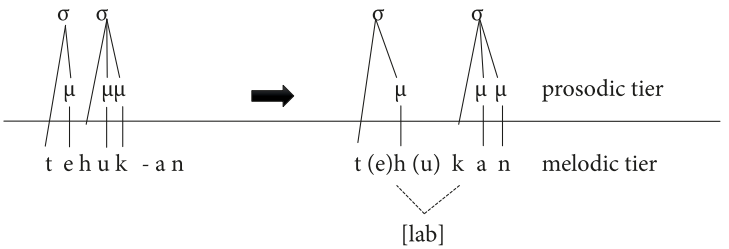
An account of the data in (10) within the traditional OR model will find difficulties in finding the trigger for vowel loss. Stems that undergo vowel reduction when suffixed may be mono- or di-syllabic, and the suffixed output may also be mono- or di-syllabic. What is consistent after suffixation is the moriac count. However, the real issue here is whether one needs the skeletal tier of segments to mediate between the moras and the root melodies. This can be seen with (10b), demonstrated in (12) below.

(12) Coarticulatory possibilities

a. With skeletal tier mediation



b. Without skeletal tier mediation

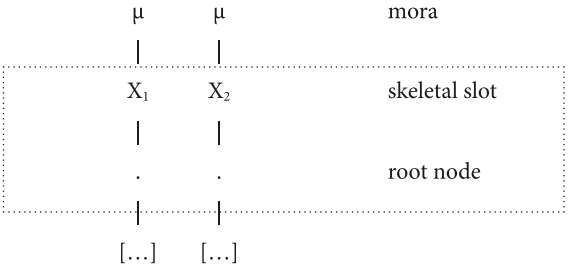


The diagram in (12a) shows a possible analysis of (10b) where mediated by the skeletal slots, the melodies are deleted when the skeletal slots taken by vowels fail to map to a mora. In (12b), a traditional μ-model is presented so that there are now no segments by melodic root nodes that are mapped directly to moras that form syllables. In a model such as (12b), the non-mapping of the [u] to a mora does not imply deletion, and hence inadequate for the case of (10b). The feature [lab] can still be associated with one of the neighboring roots to form [h^w] or [k^w]

24. [qwr] would have [w] as a sonority peak, thus an ill-formed onset. Gliding does happen in Squliq in other cases where well-formedness is obeyed, e.g. /nmbu-a/ → [mnbwa] 'to be sick' (Huang 2006). Theoretically, one might consider if a reduction to [q^w] where the labiality is now a secondary articulation and absorbed into the [q]. Such a consideration would reduce the segment to a mere feature and would still entail drastic reduction beyond gliding.

as coarticulation.[25] The reason for the difference between (12a) and (12b) can be seen though (13).

(13) Root node integrity through X slots



With a skeletal tier, the loss of X_1 may either bring with it the root node or it may not. If not, the root node may be associated elsewhere, but it would bring with it all the features. If there is no skeletal tier, effects of deletion such as that seen in (11) would have to be due to loss of the root node (cf. (12a)). However, that leaves all the features loose to associate with others (cf. (12b) but not possible in (12a)).[26] The data form Squliq thus argues for an enriched model such as (4), where skeletal slots and moras are both available.

5.3 Moras of uncertain syllabicity

As (4) predicts, moras and syllables belong to different layers. § 5.1 makes the argument for such a position by showing that there can be syllables without moras. It is possible that there are moraic entities that are not parsed into syllables. Such entities will appear to be part of other syllables while exhibiting effects of syllable weight and taking up considerable articulatory duration. Ong's

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25. The choice of deleting [e] and keeping [h] is something that both old and new models will need to explain, which happens also in (10d). A possible guess might be that since [h] is also [-consonantal], it may be preferred for reasons of (non-)footing. In these cases of tri-moraic sequences, the final two may form a foot, leaving the initial mora unfooted. These are guesses that will require further checking.

26. Moraic models have root nodes to hold the distinctive features. Root nodes therefore do the work of skeletal X slots non-moraic models of the syllable, and may provide for linear ordering of the "segmental" melodies. Crucially, however, those who wish to defend the μ-model without the use of segments, must explain what the difference is between root node and skeletal slots. Presumably, that would have to be articulatory duration, i.e. root nodes are atemporal and syllables are distinguished only by weight. Phonetically, however this cannot be true since CCCVC syllables must take longer to articulate than CVC syllables even though both types are equally bimoraic.

(2007: 59–63) study of Malaysian Cantonese provides data that suggests this effect.

Cantonese syllables are necessarily bimoraic. Allegro speech may trigger truncation, but that would apply only to minimally trisyllabic sequences where sequence medial material is reduced. Reduction comes in a number of flavors, outlined in (14).

(14) Medial reduction in trisyllabic Cantonese words
  a. Onset loss
    i. ji sɐp sam → ji-ɐ sam 'twenty-three'
    ii. pɛ tsɐu tsun → pɛ-u tsun 'beer bottle'
  b. Rhyme loss
    i. hɐm pɐŋ lɐŋ → hɐm p-lɐŋ 'all and every'
    ii. san ka la → san k-la 'remote'

(Ong 2007: 121–122)

A full analysis of the phenomenon will not be attempted here (please see Ong (2007)). Of particular interest to us are the phonotactially marked sequences that otherwise never appear in Cantonese, e.g. [iɐ] and [ɛu] in (14a), and [pl], [mp], [nk] or [kl] in (14b). In (14), we used "-" to indicate the morpheme boundary, although speakers do not appear to intuit syllable boundaries in these positions. For instance, speakers of the language are able to insert pauses only before the residue segment if it is a consonant, and a vowel if after.

(15) Available pause positions with medial residue
  a. σ_1 *<pause> V <pause> σ_3 (cf. (14a))
  b. σ_1 <pause> C *<pause> σ_3 (cf. (14b))

Ong made measurements of such normal and truncated strings in Malaysian Cantonese. Her measurements suggest that the residue of medial syllables remain moraic.

(16) Normal and truncation measurements in Malaysian Cantonese
  a. Normal speech
    i.

Trisyllabic sequence	$\sigma_{\textbf{initial}}$	$\sigma_{\textbf{medial}}$	$\sigma_{\textbf{final}}$
Duration	0.3290s	0.3322s	0.3439s
Proportion	32.27%	32.78%	34.85%

ii.

Disyllabic sequence	$\sigma_{initial}$	σ_{final}
Duration	0.3591s	0.4050s
Proportion	47.27%	52.28%

b. Truncated where residue is V (cf. (14a))

	$\sigma_{initial + medial}$	σ_{final}
Duration	0.3541s	0.2973s
Proportion	54%	46%

c. Where residue is C (cf. (14b))

	$\sigma_{initial}$	$\sigma_{medial+final}$
Duration	0.2289s	0.3849s
Proportion	38.05%	61.95%

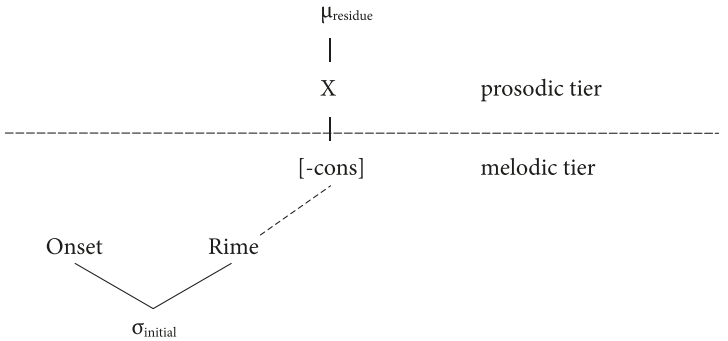
(Ong 2007: 59–63)

For cases like (14a), it is impossible to accurately locate the boundary separating the medial residue with the initial syllable; similarly for (14b) where the locus of difficulty now lies in the connection with the final syllable. Factoring for the general phonetic effects that final syllables tend to be longer (see (16a)), it is clear that the residue of the medial syllable contributes substantial duration to the truncated forms.[27]

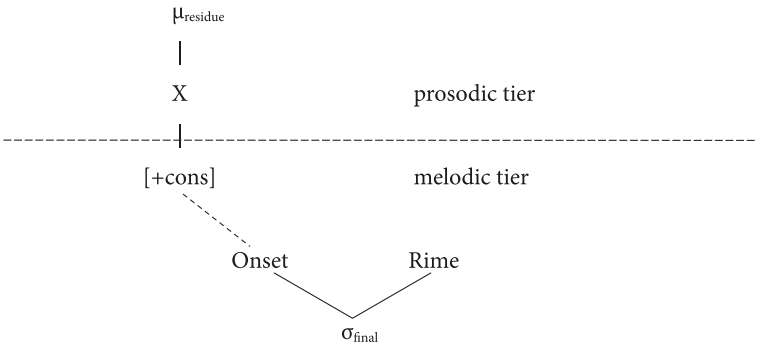
Working within a μ-model would require mora mapping to the residue. If the residue were a vowel, this would not be a problem as that would simply be a light syllable. If the residue were a consonant, that would pose a problem. The fact remains that such a consonant is not perceived as a coda (cf. (15b)). Treating it as part of a complex onset however does not explain the apparent moraicity since Malaysian Cantonese does not have moraic onsets. One could of course treat that residue consonant as syllabic, but that does not account for why pause is allowed only before, but not after that consonant. Separating the moraic and the syllabic as in the model adopted in (4) makes it easier to capture this moraic effect of the medial residue consistently, as shown in (17).

27. The measurements lead Ong to postulate syllabic consonants for the medial residue of the (14b) types. This is not necessary under the conception of the present paper.

(17) a. Where residue is V



b. Where residue is C



5.4 Moraic and syllabic ambivalence

Unlike the Malaysian Cantonese situation outlined above, ambisyllabicity is when a segment appears to be ambivalent about being in the coda of the preceding syllable or the onset of the following one. Ambisyllabicity would find easy representation in a model that recognizes both constituency and moraicity. Wee (2015) offers experimental evidence that pertain to this in particular. In his experiment, speakers of Hong Kong English are asked to provide recordings of English words normally, and then in reverse. The concept of "reverse" was deliberately left undefined to the subjects but explained though Cantonese examples where reversal is the simple reverse ordering of the syllables, e.g. 蜻蜓 [ts^{h}iŋ.t^{h}iŋ] dragonfly → [t^{h}iŋ.ts^{h}iŋ].

For polysyllabic words like *attainable* (pronounced [a.tei.ne.bou] generally across the Hong Kong English speakers), the output of the reverse articulations appear to be quite varied. For some, it is simply a reverse ordering of the syllables. Others are more complicated. There are instances where all syllables become bimoraic to produce something like [boo.aa.tiin.et], ignoring the specific differ-

ences in the quality of the vowels. There are still others where the reordered syllables are made to fit the original moraic structure, producing something like [bo.naa.ti.et]. For want of a better term, this appears to be a situation of moraic ambivalence when viewed from the angle of the syllables. Their moraic weight appears to be inconsistent in the normal and reversed forms, but the inconsistency is principled.

Moving on to ambisyllabicity, note that in instances where the output is [boo.aa.tiin.et], we witness the ambivalence of intersyllabic consonantal material. In [a.tei.ne.bou], the [n] is uttered as onset and the [t] that is not geminated. Yet, [n] becomes coda and [t] is geminated in [boo.aa.tiin.et].

The ambivalences in the moraicity of the syllables and in the syllabicity of intersyllabic consonants reflect on the looseness of association best captured in a model that separate the organization of melodies and the moraicity of segments on different tiers.

5.5 Stress-related segmental processes

The separation of the syllable and the foot raises the question of how segmental processes that relate to stress may be captured. A particular example would be the aspiration of singleton plosive onsets in stressed syllables such as that found in English and other languages.[28] Before we delve too deeply into this issue, it should be noted that it is not clear whether aspiration fortification is something phonological at all. If it is a phonetic effect that is physiologically motivated due to required intensity on the vowels, then no phonological model should try to capture it. With that qualification, assuming that there are such processes that are phonologically encoded, let us first consider how the onset-rime model and the moraic model would deal with this phenomenon.

Both the onset-rime or moraic models would require that the effect of stress percolates down to the vowels so that they diphthonize/lengthen and then upwards to the syllable and selectively to the singleton plosive onset that receives aspiration. The onset-rime model would also have to find some way of identifying the syllables that receive stress. Percolation strategies are available to the model proposed in our paper, albeit through a more circuitous route. The impact of aspiration through stress would be mediated through the "syllable" at the melodic tier.

28. We dedicate this section to the reviewer who brought this to our attention. Thank you.

6. Conclusion

This paper takes the approach that distinguishes between elements prosodic and rhythmic with elements melodic and configurational. This approach divorces the syllable from the foot into two different dimensions. This conception is unorthodox against the hierarchical organization[29] of syllables below feet. It does, however, eliminate the awkward stipulation that distinguishes moraic and syllabic languages, facilitating a coherent account of the mora and the sub-syllabic constituents as the model predicts a typology of mappings that allow onsets and/or rimes to be (un-)weighted. This has direct applications in figuring out two long-standing conundra in Chinese: the status of the medial glide and the prosodic properties of tonelessness. More importantly, the approach predicts mismatches in moraicity and syllabicity as well as the mediating effect of the skeletal slots between the melodic root nodes and their moraic status.

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Abbreviations

[cons]	[consonantal]	OR	Onset-Rime
μ	mora/moraic	T	tone
σ	syllable	V	vowel
C	consonant	X	any segment
G	glide		

29. As rightly noted by a reviewer, the syllable would no longer be part of the prosodic hierarchy in the model proposed here. Within our model, one way of capturing prosodic phenomena that had cause to appeal to the syllable is to appeal to constraints that align the boundaries of the foot to the boundaries of the syllable.

References

Ao, Benjamin. 1992. Non-uniqueness condition and the segmentation of the Chinese syllable. *OSU Working Papers in Linguistics* 41. 1–14.

Bagemihl, Bruce. 1988. *Alternate phonologies and morphologies*. University of British Columbia. (Doctoral dissertation.)

Bagemihl, Bruce. 1989. The crossing constraint and "backwards languages". *Natural Language and Linguistic Theory* 7(4). 481–549. https://doi.org/10.1007/BF00205156

Bagemihl, Bruce. 1995. Language games and related areas. In Goldsmith, John A. (ed.), *The handbook of phonological theory*, 697–712. Cambridge: Blackwell.

Bao, Zhiming. 1990. *Fanqie* languages and reduplication. *Linguistic Inquiry* 21(3). 317–350.

Baxter, William. 1992. *A handbook of Old Chinese phonology*. Berlin: Mouton de Gruyter. https://doi.org/10.1515/9783110857085

Blevins, Juliette. 1995. The syllable in phonological theory. In Goldsmith, John (ed.), *The handbook of phonological theory*, 206–245. Cambridge: Blackwell.

Broselow, Ellen. 1995. Skeletal positions and moras. In Goldsmith, John (ed.), *The handbook of phonological theory*, 175–205. Cambridge: Blackwell.

Cai, Jun Jun. 2005. *Yinjie jiegou – sanzhong Beijing danqieyu de zhengju* [Syllable structure: Evidence from three Beijing fanqie languages]. (http://staffweb.hkbu.edu.hk/lianhee/Student%20Works/Cai-jj2005.pdf) (Accessed 2021-07-09.)

Cao, Jianfen. 1986. Putonghua qingsheng yinjie texing fenxi [An analysis on the character of Putonghua light tone]. *Yingyong Shengxue* [Journal of Applied Acoustics] 1986(4). 1–6.

Cao, Jianfen. 1995. Liandu biandiao yu qingzhong duili [Tone sandhi and weight contrast]. *Zhongguo Yuwen* [Studies of the Chinese Language] 1995(4). 312–320.

Chao, Yuen Ren. 1931. Fanqieyu bazhong [Eight types of Fanqie languages]. *Zhongyanyuan Shiyusuo Jikan* [Bulletin of the Institute of History and Philology] 2(3). (Reprint in *Zhaoyuanren Yuanxue Lunwenji* [The collection of Chao Yuen-ren's papers], 362–404. Beijing: The Commercial Press.)

Chao, Yuen Ren. 1934. The non-uniqueness of phonemic solutions of phonetic systems. *Bulletin of the Institute of History and Philology, Academia Sinica* 4(4). 363–398. (Reprinted in *Readings in linguistics I*, 38–54. Chicago: Chicago University Press.)

Chen, Matthew Y. 2000. *Tone sandhi: Patterns across Chinese dialects*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511486364

Chen, Yiya & Xu, Yi. 2006. Production of weak elements in speech: Evidence from F_0 Patterns of neutral tone in Standard Chinese. *Phonetica* 63(1). 47–75. https://doi.org/10.1159/000091406

Cheng, Chin-chuan. 1973. *A synchronic phonology of Mandarin Chinese*. The Hague: Mouton. https://doi.org/10.1515/9783110866407

Cheng, Robert L. 1966. Mandarin phonological structure. *Journal of Linguistics* 2(2). 135–158. https://doi.org/10.1017/S0022226700001444

Cheung, Kwan-hin. 1986. *The phonology of present-day Cantonese*. London: University of London. (Doctoral dissertation.)

Chomsky, Noam & Halle, Morris. 1968. *The sound pattern of English*. New York: Harper & Row.

Deng, Dan & Chen, Ming & Lü, Shinan. 2004. Hanyu qusheng he qingsheng yinjiede yunlü tezheng yanjiu [The study of the prosodic features of Mandarin tone-4 and tone-5]. *Yuyan Kexue* [Linguistic Sciences] 2004(2). 20–28.

Department of Chinese Language and Literature, Peking University (ed.). 1995. *Hanyu fangyan cihui* [The lexicon of Chinese dialects]. Beijing: Language and Culture Press.

Dhillon, Rajdip. 2007. Stress in Punjabi. *Proceedings of the Berkeley Linguistic Society* 33. 84–95. https://doi.org/10.3765/bls.v33i1.3519

Duanmu, San. 1990. *A formal study of syllable, tone, stress and domain in Chinese languages*. Cambridge: MIT. (Doctoral dissertation.)

Duanmu, San. 2007. *The phonology of standard Chinese*. 2nd edn. New York: Oxford University Press. (1st edition published in 2000.)

Duanmu, San. 2009. *Syllable structure: The limits of variation*. New York: Oxford University Press.

Egerod, Søren. 1965. Verb inflexion in Atayal. *Lingua* 15. 251–282. https://doi.org/10.1016/0024-3841(65)90015-X

Feng, Shengli. 1997. *Hanyu de yunlu, cifa yu jufa* [Interactions between morphology, syntax and prosody in Chinese]. Beijing: Peking University Press.

Feng, Shengli. 1998. Lun Hanyu de "ziran yinbu" [On "natual feet" in Chinese]. *Zhongguo Yuwen* [Studies of the Chinese Language] 1998(1). 40–47.

Feng, Shengli. 2001. *Minimal word in Mandarin Chinese* (Rutgers Optimality Archive 507). (http://roa.rutgers.edu/article/view/517) (Accessed 2018-04-18.)

Feng, Yongqiang & Chu, Min & He, Lin & Lü, Shinan. 2001. Hanyu huayu yinjie shichang tongji fenxi [A statistical analysis of syllable length in Chinese discourse]. In Cai, Lianhong & Zhou, Tongchun & Tao, Huajian (eds.), *Xinshijide xiandai yuyinxue – Diwujie Quanguo Xiandai Yuyinxue Xueshuhuiyi lunwenji* [Modern phonetics of the new century – Proceedings of the 5th National Conference on Modern Phonetics], 74–77. Beijing: Tsinghua University Press.

Fu, Jingqi. 1990. Labial-labial cooccurrence restrictions and syllabic structure. In Meyer, Denis & Tomioka, Satoshi & Zidani-Eroglu (eds.), *Proceedings of the 1st Meeting of the Formal Linguistic Society of Mid America (FLSM 1)*, 129–144. Madison: University of Wisconsin Press.

Fudge, Erik. 1969. Syllables. *Journal of Linguistics* 5(2). 253–286. (In-text citation based on reprint. In Goldsmith, John (ed.), *Phonological theory: The essential readings*, 370–391. Malden: Blackwell.) https://doi.org/10.1017/S0022226700002267

Goh, Meow Hui. 2015. The rhyme book culture of Pre-Tang China. *Journal of Chinese Literature and Culture* 2(2). 419–443. https://doi.org/10.1215/23290048-3324164

Goh, Yeng-Seng. 2000. Beijinghua shi danyinjie yuyan de zhiyi [Is Beijing Madarin a monosyllabic language?]. *Dangdai Yuyanxue* [Contemporary Linguistics] 2000(4). 231–247.

Goldsmith, John. 1976. Autosegmental phonology. Cambridge: MIT. (Doctoral dissertation.)

Gordon, Matthew. 1999. *Syllable weight: Phonetics, phonology and typology*. Los Angeles: UCLA. (Doctoral dissertation.) (https://linguistics.ucla.edu/images/stories/Gordon.1999.pdf) (Accessed 2021-07-09.)

Gordon, Matthew. 2002. A phonetically-driven account of syllable weight. *Language* 78(1). 51–80. https://doi.org/10.1353/lan.2002.0020

Hayes, Bruce. 1989. Compensatory lengthening in moraic phonology. *Linguistic Inquiry* 20(2). 253–306.

Hayes, Bruce. 1995. *Metrical stress theory: Principles and case studies*. Chicago: University of Chicago Press.

Hirsch, Aaron. 2014. What is the domain for weight computation: The syllable or the interval? In Kingston, John & Moore-Cantwell, Claire & Pater, Joe & Staubs, Robert (eds.), *Proceedings of the 2013 Meeting on Phonology*. Washington, D.C.: Linguistic Society of America. (https://journals.linguisticsociety.org/proceedings/index.php/amphonology/article/view/21) https://doi.org/10.3765/amp.v1i1.21

Hock, Hans Henrich. 1986. *Compensatory lengthening: In defense of the concept "Mora". Folia Linguistica* 20(3–4). 431–460.

Holtman, Astrid. 1996. *A generative theory of rhyme: An optimality approach*. Utrecht: Utrecht University. (Doctoral dissertation.)

Hsieh, Feng-fan. 2017. "Shengmu canzhong" de yuyin ji yinxi liju [A critical review of recent approaches to onset weight: with special reference to the "medial"(onglides) in Chinese]. *Yunlü Yufa Yanjiu* [Studies in Prosodic Grammar] 2(2). 32–51.

Hsieh, Feng-fan. 2018. Temporal organization of the "medials" in Standard Chinese. (Paper presented at the First Symposium of Frontiers in Chinese Linguistics, Hong Kong, 8–9 June 2018.)

Huang, Hui-chuan J. 2006. Resolving vowel clusters: A comparison of Isbukun Bunun and Squliq Atayal. *Language and Linguistics* 7(1). 1–26.

Huang, Hui-chuan J. 2018. The nature of pretonic weak vowels in Squliq Atayal. *Oceanic Linguistics* 57(2). 265–288. https://doi.org/10.1353/ol.2018.0012

Hyman, Larry M. 1985. *A theory of phonological weight*. Dordrecht: Foris. https://doi.org/10.1515/9783110854794

Hyman, Larry M. 1987. Prosodic domains in Kukuya. *Natural Language and Linguistic Theory* 5(3). 311–333. https://doi.org/10.1007/BF00134552

Jakobson, Roman & Fant, C., Gunnar, M. & Halle, Morris. 1951. *Preliminaries to speech analysis: The distinctive features and their correlates*. Cambridge: The MIT Press.

Kager, René. 1990. Dutcha schwa in moraic phonology. In Ziolkowski, Michael & Noske, Manuela & Deaton, Karen (eds.), *Papers from the 26th Regional Meeting of the Chicago Linguistic Society volume 2: The parasession on the syllable in phonetics and phonology*, 241–255. Chicago: Chicago Linguistic Society.

Kelly, Michael H. 2004. Word onset patterns and lexical stress in English. *Journal of Memory and Language* 50(3). 231–244. https://doi.org/10.1016/j.jml.2003.12.002

Kurylowicz, Jerszy. 1948. Contribution à la Theorie de la Syllabe [Contribution to the theory of the syllable]. *Bulletin de la Societe Polonaise de linguistique* 8. 80–114.

Leben, William Ronald. 1973. *Suprasegmental phonology*. Cambridge: MIT. (Doctoral dissertation.)

Levin, Juliette. 1985. *A metrical theory of syllabicity*. Cambridge: MIT. (Doctoral dissertation.)

Li, Mingxing. 2004. *Neutral tone in disyllabic sequences across Chinese dialects: An OT account*. Tianjin: Tianjin Normal University. (Master's thesis.)

Li, Rong. 1983. Guanyu fangyan yanjiu de ji dian yijian [Some comments on dialectal studies]. *Fangyan* [Dialect] 1983(1). 1–15.

Liang, Lei. 2007. Hanyu qingshengde lishi cengci tansuo [A preliminary study on the historical stratum of the neutral tone in Chinese]. *Nankai Yuyanxuekan* [Nankai Linguistics] 2007(2). 32–38.

Lin, Maocan & Yan, Jingzhu. 1980. Beijinghua qingsheng de shengxue xingzhi [Acoustic properties of tonelessness in Mandarin]. *Fangyan* [Dialect] 1980(3). 166–178.

Lin, Maocan & Yan, Jingzhu. 1990. Putonghua qingheng yu qingzhongyin [Light tone and heavy light accent in Putonghua] *Yuyan Jiaoxue yu Yanjiu* [Language Teaching and Linguistic Studies] 1990(3). 88–104.

Lin, Tao. 1985. Tantao Beijinghua qingyin xingzhi de chubu shiyan [Preliminary experiments in the exploration of the nature of Mandarin neutral tone]. In Lin, Tao & Wand, Lijia (eds.), *Beijing yuyin shiyan lu* [Working papers in experimental phonetics], 1–26. Beijing: Peking University Press.

Lin, Yen-Hwei. 1989. *Autosegmental treatment of segmental processes in Chinese phonology*. Austin: The University of Texas at Austin. (Doctoral dissertation.)

Moon, Christine & Fifer, William P. 1990. Syllables as signals for 2-day-old infants. *Infant Behavior and Development* 13(3). 377–390. https://doi.org/10.1016/0163-6383(90)90041-6

Ong, Yin Hsiar. 2007. *Phonological elision in Malaysian Cantonese casual speech*. Singapore: National University of Singapore. (Master's thesis)

Pan, Wuyun. 2006. Hanyu de yinjie miaoxie [The description of Chinese syllables]. *Linguistic Sciences* [Linguistic Sciences] 5(2). 39–43.

Pandey, Pramod Kumar. 1989. Word accentuation in Hindi. *Lingua* 77(1). 37–73. https://doi.org/10.1016/0024-3841(89)90038-7

Pike, Kenneth L. & Pike, Eunice Victoria. 1947. Immediate constituents of Mazateco syllables. *International Journal of American Linguistics* 13(2). 78–91. https://doi.org/10.1086/463932

Srinivas, Sampath Kumar. 2012. Onset prominence in Optimality Theory. *The EFL Journal* 3(2). 45–64.

Srinivas, Sampath Kumar. 2016. *The Mora-constituent interface model*. Hong Kong: Hong Kong Baptist University. (Doctoral dissertation.)

Sun, Jingtao. 2006. Jieyin zai yinjie zhong de diwei [The status of medial in syllable]. *Yuyan Kexue* [Linguistic Sciences] 5(2). 44–52.

Teinonen, Tuomas & Fellman, Vineta & Näätänen, Risto & Alku, Paavo & Huotilainen, Minna. 2009. Statistical language learning in neonates revealed by event-relate brain potentials. *BMC Neuroscience* 10(21). (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2670827/pdf/1471-2202-10-21.pdf) (Accessed 2018-04-01.)

Topintzi, Nina. 2008. On the existence of moraic onset geminates. *Natural Language and Linguistic Theory* 26(1). 147–184. https://doi.org/10.1007/s11049-008-9034-4

Topintzi, Nina. 2010. *Onsets: Suprasegmental and prosodic behaviour*. New York: Cambridge University Press. https://doi.org/10.1017/CBO9780511750700

Trubetzkoy, Nikolai Sergeevich. 1969[1939]. *Vandenhoeck and Ruprecht* [Principles of phonology]. Berkeley: University of California Press. (Translated by Baltaxe, Christiane A.M.) (see also the French edition published in 1964 under the title: *Principes de phonologie*. Paris: Klincksieck. Translated by Cantineau, J.)

Vijayakrishnan, K.G. 1978. *Stress in Tamilian English: A study within the framework of generative phonology*. Hyderabad: Central Institute of English and Foreign Languages. (Master's thesis.)

Vijayakrishnan, K.G. 2002. The disyllabic trochee in Bangla, Punjabi and Tamil: Variations on a theme. (Paper presented at GLOW in Asia 2002, Hsinchu, 4–7 January 2002.) (http://glow.ling.nthu.edu.tw/Vijayakrishnan.pdf) (Accessed 2018-04-12.)

Wang, Jenny Zhijie. 1993. *The geometry of segmental features in Beijing Mandarin*. University of Delaware. (Doctoral dissertation.)

Wang, Jialing. 2002. Sanzhong fangyan qingsheng de youxuanlun fenxi [An OT analysis of neutral tone in three Chinese dialects]. *Yuyan Kexue* [Linguistic Sciences] 2002(1). 78–85.

Wee, Lian-Hee. 2004. *Inter-tier correspondence theory*. New Brunswick: Rutgers University. (Doctoral dissertation.)
Wee, Lian-Hee. 2011. Syllable as part of i-grammar: Approaching the Chinese medial glide problem through rhyming patterns. *Nanfang Yuyanxue* [Linguistics of the South] 3. 160–170.
Wee, Lian-Hee. 2015. *Normal and reversed articulations of English words by Cantonese speakers*. Hong Kong: Hong Kong Baptist University. (Recordings and transcriptions).
Wee, Lian-Hee. 2020. A spin to preserve contrast: Taiwanese tone sandhi. *Stellenbosch Papers in Linguistics Plus (SPiL Plus)* 60. 13–29. https://doi.org/10.5842/60-0-755
Wee, Lian-Hee. Forthcoming. Tonal processes conditioned by morphosyntax. In Huang, C.-T. James & Lin, Yen-Hwei & Chen, I-Hsuan (eds.), *The Cambridge handbook of Chinese linguistics*. Cambridge: Cambridge University Press.
Xu, Yi. 1997. Contextual tonal variations in Mandarin. *Journal of Phonetics* 25(1). 61–83. https://doi.org/10.1006/jpho.1996.0034
Yan, Hanbo. 2018. *The nature of variation in tone sandhi patterns of Shanghai and Wuxi Wu*. Singapore: Springer. https://doi.org/10.1007/978-981-10-6181-3
Yin, Hui. 2002. Faithfulness and markedness in Mandarin tone sandhi. (Paper presented at the Eighth International Symposium on Chinese Languages and Linguistics, Taipei, 8–10 Novermber 2002.)
Yip, Moira. 2003. Casting doubt on the Onset-Rime distinction. *Lingua* 113(8). 779–816. https://doi.org/10.1016/S0024-3841(02)00130-4
Yupho, Nawanit. 1989. Consonant clusters and stress rules in Pattani Malay. *Mon-Khmer Studies Journal* 15. 125–137.
Zee, Eric. 1991. Chinese (Hong Kong Cantonese). *Journal of International Phonetic Association* 21(1). 46–48. https://doi.org/10.1017/S0025100300006058
Zhang, Xiao-yu. 1977. *Qingsheng bianyi juli* [Minimal pairs of tonal reduction]. Taiwan: Xuehai Chubanshe.
Zwicky, Arnold M. 1976. Well, this rock and roll has got to stop. Junior's head is hard as a rock. In Mufwene, Salikoko S. & Walker, Carol A. & Steever, Sanford B. (eds.), *Proceedings of the 12th Annual Meeting of the Chicago Linguistics Society*, 676–697. Chicago: Chicago Linguistic Society.

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