



A Perceptually-based Approach to Chinese Syllable-Tone Patterning

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Abstract

Syllable structure is systematically related to tone patterning in two dimensions: sonority and duration. The reasons for this are fundamentally phonetic: syllable weight is determined by the sonority and duration profile of the rhyme, which themselves are the phonetic correlates of tone. This paper uses the Moraic Model [1] to analyze the weight-mediated syllable-tone patterning in four distinct Chinese languages, and a perceptually-based approach to provide a functional explanation. It is found that a one-to-one patterning between weight and tone units is more commonly found in Chinese languages, whereas the one-to-many patterning between units of the two tiers is much less common.

Index Terms: Moraic Model, perceptually-based approach, syllable structure, tone, weight

1. Introduction

It is widely recognized that there is a systematic correlation between syllable structure and tone patterns. Generally speaking, the more sonorant segments a syllable has, the more likely it is to bear a tone or a stress [2][3]. For example, In Kiowa, the tonal system makes a distinction between $CVC_{[+son]}$ and $CVC_{[-son]}$ syllables, so that all CVV and $CVC_{[+son]}$ syllables are heavy and can bear a contour tone, whereas all $CVC_{[-son]}$ and CV syllables are light and can only bear a level tone. The Yana stress system, on the other hand, makes a distinction between $CVC_{[-son]}$ and CV syllables, so that all CVV , $CVC_{[+son]}$ and $CVC_{[-son]}$ syllables are heavy and can be stressed, whereas all CV syllables are light and cannot be stressed.

A similar correlation between syllable structure and tone is also observed across Chinese languages. Evidence includes: (i) Chinese languages with coda contrast and diphthongal nuclei have contour tones, whereas those without coda contrast or diphthongal nuclei only have level tones [4][5]; (ii) there is a systematic patterning of “smooth” rhymes with “smooth” tones and of “checked” rhymes with “checked” tones across Chinese languages; (iii) diachronically, many Chinese languages have undergone a smoothing process of checked rhymes accompanied by the loss of non-sonorant consonantal codas (such as /p t k/) from Middle Chinese onwards [6][7]; (iv) patterning of full contour tones with complex rhymes and of zero tones with simple rhymes occurs in Standard Chinese (SC), as well as reduction of complex rhymes to simple rhymes when contour tones are reduced to level tones [8][9].

This paper argues that syllable structure and tone in Chinese are mediated through the weight tier, whose justification is grounded in phonetics. It then shows that a perceptually-based approach is able to provide a functional explanation for the weight-mediated syllable structure-tone patterning in four distinct Chinese languages.

2. A Moraic Account: Its Phonetic Grounds and Phonological Consequences

The Moraic Model for Chinese Syllable Structure-Tone Patterning was formalized and argued for in [1]. It is schematized as follows, with slight adaptations:

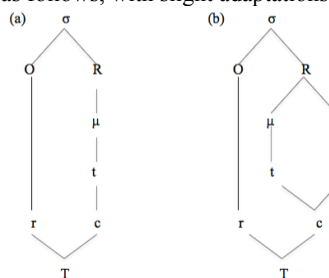


Figure 1: Schematic illustration of the Moraic Model.

The main idea of this model is that syllable weight, which is measured in moras, is the unifying tier between syllable structure and tone. This can be justified phonetically: syllable weight is determined by the sonority and duration profile of the rhyme, which on the other hand are the phonetic correlates of tone [10][11].

There are three widely accepted facts about syllable weight: (1) syllable onsets do not affect the weight of a syllable [3][12][13]; (2) the more sonorant a segment is, the more likely it is to be a weight-bearing unit. Roca [14] proposed the following sonority hierarchy for segments in general:

- (1) $V > G(\text{lides}) > L(\text{liquids}) > N > C[+\text{voice}] > C[-\text{voice}]$

Languages differ as to how they divide this hierarchy and allow it to interact with syllable structure: some languages only count CVV syllables as heavy whereas others count both CVV and CVC as heavy. The key fact is that if CVC is counted heavy in a language, then CVV must also be heavy in that language. The converse is not true; (3) the more sonorant segments a rhyme has, the more likely it is to be heavy in weight. Evidence is that in all languages that contrast in vowel length, CVV syllables are always heavy whereas CV syllables are always light [3][10][11]. All these facts and those mentioned in section 1 justify the conclusion that sonority and duration in the rhyme define the weight profile of the syllable.

On the other hand, it is agreed that the most important phonetic cue for tone is fundamental frequency F_0 . Only voiced segments have F_0 whereas voiceless ones don't. Therefore, only voiced segments can carry a tone. While all voiced segments have fundamental frequency, they differ in the magnitude of fundamental frequency. Generally speaking, vowels have the most intense fundamental frequency, whereas consonants have the least intense fundamental frequency. The acoustic intensity of fundamental frequency correlates with sonority in perception. Therefore, vowels are the ideal segments to bear a tone because they provide the best cues for the perception of fundamental frequency, whereas stops are the least suited because they provide the least cues for the perception of fundamental frequency.

In addition, articulatorily speaking, it takes time for a contour tone to be realized. The more complex a tone is in terms of contour, the longer time it will take for it to be realized, compared to non-complex tones. For example, other things being equal, it takes longer for an MLH tone to be realized than MH. In terms of contour perception, the pitch contrast of level tones within a contour and the pitch transition are important cues for the listeners to accurately perceive the contour tone. In summary, within a reasonable range, the longer the duration of a contour tone is, the easier it is for a speaker to produce the contour, and the easier it is for the listener to perceive it. Greenberg and Zee (1979) show that listeners cannot perceive pitch changes reliably when the duration is below 90ms [11].

Note that syllable weight and tone are not only phonetic facts but also phonological constructs, which means that when studying syllable-tone patterning, we should not only consider its phonetic grounding but, more importantly, its phonological consequences, i.e. the patterns of contrast in syllable weight and in tone. Generally speaking, there are three possible patterns of weight contrast and tonal contrast: (i) one mora patterns with one level tone, as illustrated in Figure 1; (ii) one mora patterns with more than one level tone; (iii) one level tone patterns with more than one mora. The schematic illustrations of (ii) and (iii) are given below:

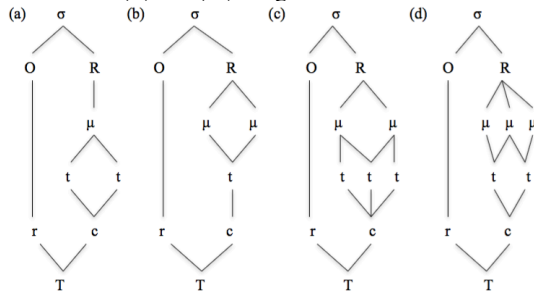


Figure 2: Schematic illustration of mora-tone patterns

The syllable-tone patterning in Figure (2a) illustrates a checked rhyme which a short contour tone, which occurs in many Chinese languages; Figure (2b) could represent a syllable in a language with a stress-like tonal system where tones may contrast in length. This patterning is not attested in this study; Figure (2c) could represent a language with a three-way contrast in tone contour but only a two-way contrast in weight; this occurs in Zhenhai monosyllables in the citation form, as we will see in section 3; Figure (2d) could represent a language which has a three-way contrast in syllable weight but only a two-way tone contrast, which is not attested in this study, either.

The general prediction of the Moraic Model is that any change in the sonority and/or duration of the syllable rhyme that causes a change in the syllable weight will result in a change of the tone it bears, and vice versa.

3. A Perceptually-based Approach

The Moraic Model is effective in representing the syllable structure-tone patterning in major Chinese languages, but it does not provide sufficient explanation as to why and how this patterning comes about. The perceptually-based approach in phonology provides a functional explanation to it.

The perceptually-based approach in phonology is based on two major theories: the P-map Theory [15] and the Dispersion Model of Contrast [16][17][18]. The crucial point

of the two theories is that the purpose of effective communication is best achieved by phonological systems that have maximally distinct contrasts, which are first and foremost perceptually grounded, and that the presence of a contrast in a particular environment is licensed by the availability of perceptual cues to that contrast. These hypotheses can be formalized with three OT constraints: MINDIST, MAXCONTRAST and EFFORT MINIMIZATION.¹ The first constraint is a markedness constraint which specifies the dimension of contrast and the minimal distance in contrast; the second constraint is a faithfulness constraint which requires that all existing contrasts in the base be preserved in the surface form, and the third constraint says that we should make the least amount of effort in realizing the contrast. That is to say, the ideal phonetic realization for a phonological contrast should require the least production effort but achieve the maximal perceptual distinction. Actual phonological systems are always the results of a compromise between efforts and perceptual distinction, as long as they can achieve effective communication.

Three MINDIST constraints, i.e. MINDIST=[+son], MINDIST=μ, and MINDIST=T, are used in this study. The symbol immediately following the equation sign (=) specifies the dimension in focus, and the number following the dimension stipulates the specific minimal distance between components in the candidate along this dimension. For example, MINDIST=[+son]:1 states that the minimal sonority difference between rhymes in the candidate should be one sonorant segment apart. Any candidate that does not have rhymes that are one sonorant segment apart is penalized. Therefore, Candidate (VV, V) satisfies this constraint, whereas Candidate (VV, VG) and Candidate (VGN, V) violate this constraint, because the minimal sonority distance between VV and VG is 0, and that between VGN and V is two.

Specific markedness constraints are also used in this study. For example, *3[+son], *3μ, and *3T are three markedness constraints that give violation marks to any candidate that has three sonorant segments in a row, is super-heavy in weight, and bears three level tones, respectively.

This study analyses syllable structure-tone patterning in four distinct Chinese languages---Mandarin Chinese (MC), Shanghaiese, Cantonese and Zhenhai dialect. It shows that the Moraic Model is able to capture the patterns in these Chinese languages, and that the perceptually-based approach is able to provide an explanation for all these patterns.

3.1. Mandarin Chinese (MC)

Mandarin Chinese (MC) is also known as Standard Chinese. Its rhyme structure and citation tone inventory is given below [19][20]:

(2) Rhyme inventory: VV, VG, VN, V

Tone inventory: 55 (T1), 35 (T2), 21 (T3), 51 (T4), 0 (T5)

Tone 3 is controversial as to whether it should be regarded as 21 or 214. This paper assumes the former transcription because: (i) on the surface form, Tone 3 only occurs as 214 phrase-finally, whereas it is 21 elsewhere. The phonological rule is more natural and economical if T3 is 21 than if it is 214; (ii) Phonetic experiments [21] have shown that Tone 3 is basically a low tone. The rise at the end of the tone is

¹ EFFORT MINIMIZATION is mainly used to capture co-articulation, which is not relevant in our study.

caused by an “Edge Effect” which could be regarded as a tone sandhi process.

In MC, heavy syllables usually have two sonorant segments in the rhyme (VV, VN, VG), which pattern with contour tones, whereas light syllables have only one sonorant segment in the rhyme (V), which pattern with the zero tone. Therefore, the constraint rankings on the syllable tier, the weight tier and the tone tier in MC are as follows:

- (3) *3[+son]>>MINDIST=[+son]:1>>MAXCONTRAST
 *3 μ >>MINDIST= μ :1>>MAXCONTRAST
 *3T>>MINDIST=T:1>>MAXCONTRAST

Illustrative OT tableaux for MC syllable-tone patterning are as follows:

Tableaux 1: MC rhyme-weight-tone patterning.

Base: VV, VG, VN, VGN, V	*3[+son]	MINDIST=[+son]:1	MAXCONTRAST
a. VV, VG, VN, VGN, V	*!		✓✓✓✓
☛ b. VV, VG, VN, V			✓✓✓✓
c. VV, VG, V			✓✓✓!
d. VGN, V	*!	*	✓✓
e. VV, V			✓✓!
f. VV			✓!
g. V			✓!
Base: $\mu\mu, \mu, \mu$	*3 μ	MINDIST= μ :1	MAXCONTRAST
a. $\mu\mu, \mu, \mu$	*!		✓✓✓
b. $\mu\mu, \mu$	*!	*	✓✓✓
☛ c. μ, μ, μ			✓✓
d. $\mu\mu$			✓!
e. μ			✓!
Base: tt, t	*3T	MINDIST=T:1	MAXCONTRAST
a. tt, t, t	*!		✓✓✓
b. tt, t	*!	*	✓✓
☛ c. tt, t			✓✓
d. tt			✓!
e. t			✓!

That is to say, syllable-tone patterning in MC can be captured by Figures (1a&b) above: there is only a two-way contrast in all three tiers, and every segment in the rhyme bears a mora, which in turn patterns with a level tone. The reason is that the constraint that penalizes super-heavy syllables in MC outranks the constraints that maximize contrast in its phonological system.

3.2. Shanghaiese

Shanghaiese is spoken mostly in east China’s Shanghai Municipality, and is a subdialect of the Wu language family. In this study, we analyze the New Shanghaiese variety, which is spoken mainly in the modern inner city. The rhyme and tone inventories of New Shanghaiese are listed below [22]:

- (4) Rhyme inventory: VV, VN, V?

Tone inventory: 53, 34, 23, 55, 12

Shanghaiese is well known for the simplicity in its rhyme structure, i.e. there are no diphthongs in Shanghaiese, and VN is usually realized as a nasalized vowel. It is also well-known for its distinctive tone sandhi pattern: all underlying tones of the syllables in a multi-syllabic prosodic word are deleted except for the tone of the first syllable, which splits into two simple level tones, the second of which spreads to its right-hand neighbor in a prosodic phrase. For example,

- (5) se. pe. tejø “three glasses of wine”
 HL.HL.LM base tone
 H. L. L sandhi tone

That is to say, New Shanghaiese only allows simple rhymes and an H/L tonal contrast on the surface form. Therefore, the constraint rankings on the syllable tier, the weight tier and the tone tier in Shanghaiese are as follows:

- (6) *2[+son]>>MINDIST=[+son]:0>>MAXCONTRAST
 *2 μ >>MINDIST= μ :0>>MAXCONTRAST
 *2T>>MINDIST=T:0>>MAXCONTRAST

The syllable-tone patterning in Shanghaiese is illustrated in Tableaux 2.

Tableaux 2: Shanghaiese rhyme-weight-tone patterning.

Base: VV, VN, V	*2[+son]	MINDIST=[+son]:0	MAXCONTRAST
a. VV, VN, V	*!		✓✓✓
b. VV, V	*!		✓✓
c. VN, V	*!		✓✓
☛ d. V (V?)			✓
Base: $\mu\mu, \mu$	*2 μ	MINDIST= μ :0	MAXCONTRAST
a. $\mu\mu, \mu$	*!		✓✓
b. $\mu\mu$	*!		✓
☛ c. μ			✓
Base: tt, t	*2T	MINDIST=T:0	MAXCONTRAST
a. tt, t	*!		✓✓
b. tt	*!		✓
☛ c. t			✓

That is to say, Shanghaiese syllable-tone patterning on the surface form was captured by Figure (1a): there is no contrast between any of the three tiers. The reason is that the markedness constraint that penalizes contrast outranks the constraints that allow contrast in the Shanghaiese phonological system.

3.3. Cantonese

Cantonese is mainly spoken in southeast China’s Cantonese Province. The following is the rhyme inventory and tone inventory in Cantonese [19][23]:

- (7) Rhyme inventory: V:, V:G, V:N, VG, VN, V:P, VP

Tone inventory: 55, 35, 33, 5, 21, 13, 22, 2, 3

At the first sight, Cantonese seems to have a three-way contrast in its rhyme structure such as V:N, VN, and VP. But in fact, since the length contrast in vowels is defective, there is only a two-way contrast. The evidence is as follows: (i) for each nuclear vowel except for /a/, there is no rhyme contrast like V:N, VN, and VP. Instead, V:N only contrast with V:P whereas VN only contrast with VP. For example, [i:m] and [i:n] only contrast with [i:p] and [i:t] respectively, whereas [in] only contrast with [ik]; (ii) there is a “complementary mechanism” between nucleus and coda in terms of duration so that V:G and V:N are of the same duration as VG and VN---when the nucleus is short, the coda is long [19][20][23]; (iii) there is no significant durational difference between unchecked rhymes in Cantonese, i.e. V:G and V:N are similar in duration to V:, VG and VN [1][19][23]. Duanmu [19] attributed the durational difference between vowels to a quality contrast, and reduce the rhyme inventory in Cantonese to only four: VV, VG, VN and VP. In this study, we propose that phonetically speaking, Cantonese does allow its rhymes to contain three sonorant segments; however, it does not allow a three-way contrast between them. That is to say, there is only a two-way contrast in Cantonese syllable weight. There is no superheavy syllable in Cantonese.

In addition, Cantonese has very few tone sandhi rules, except for certain morphologically related cases, which do not change the sonority or duration of the syllable. That is to say, Cantonese only allows a two-way contrast in tone contour. Therefore, the constraint rankings on the syllable tier, the weight tier and the tone tier in Cantonese are as follows:

- (8) MINDIST=[+son]:1>>MAXCONTRAST>>*3[+son]
 *3 μ >>MINDIST= μ :1>>MAXCONTRAST
 *3T>>MINDIST=T:1>>MAXCONTRAST

The OT tableaux for syllable-tone patterning in Cantonese are as follows:

Tableaux 3: *Cantonese rhyme-weight-tone patterning.*

Base: V:, V:G, V:N, VG, VN, V:P, VP	MINDIST = [+son]: 1	MAXCONTRAST	*3[+son]
a. V:, V:G, V:N, VG, VN, V:P, VP		//////	**
b. V:, V:G, V:N, VP	*!	////	**
c. VV, VG, VN, V:P	*!	////	
d. VV, VG, VN, VP		////!	
e. VV, VG, VN		////!	
Base: μμ, μμ, μ	*3μ	MINDIST=μ: 1	MAXCONTRAST
a. μμ, μμ, μ	*!		///
b. μμ, μ	*!	*	///
c. μμ, μ			///
d. μμ			!/
e. μ			!/
Base: tt, tt, t	*3T	MINDIST=T: 1	MAXCONTRAST
a. tt, tt, t	*!		///
b. tt, t	*!	*	///
c. tt, t			///
d. tt			!/
e. t			!/

As can be seen from the analysis, syllable-tone patterning in Cantonese is captured by Figure 1: one mora patterns with one level tone. The reason is that on the weight and tone tiers, the constraints that penalize super-heavy syllables and complex tones, respectively, outrank those that maximize the contrast.

3.4. Zhenhai Dialect

Zhenhai dialect is a subdialect of the Wu languages, spoken in south China's Zhejiang Province. Citation forms of Zhenhai rhymes and tones are listed below (adapted from [24]):

(9) Rhyme inventory: VV, VN, VG (few), V?

Tone inventory: 51, 324, 232, 213, 5q, 23q

Rose [24] quantified the durational relationship between all syllable types in Zhenhai dialect by measuring the individual syllable types as a percentage of the longest duration value. The results show that the duration of syllables ending with the glottal stop is less than 40% of the reference duration value, whereas duration of syllables that end in a vowel, glide or nasal are above 60% of the reference value [24]. The study concludes that in general, there is only a two-way contrast in Zhenhai syllable rhymes: [-long] vs. [+long]. In addition, the disyllabic words in Zhenhai have two prosodic patterns: SW (strong-weak) and WS (weak-strong). Syllables with smooth rhymes can appear both in strong and weak positions, whereas those with checked rhymes appear only in weak position [9]. This fact shows that there is only a two-way contrast in Zhenhai syllable weight: μμ vs. μ.

Zhenhai tonal system on monosyllables is given in Figure 3 below [25]:

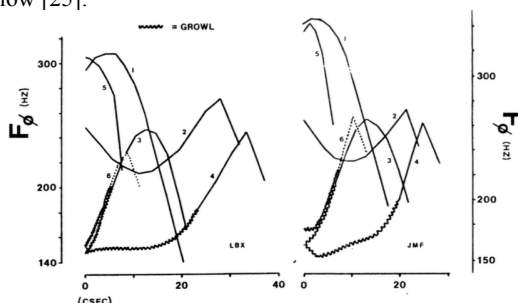


Figure 3: *Mean fundamental frequency shapes of Zhenhai tonemes by two native speakers*

As can be seen from the figure above, there are rising, falling, concave and convex tones in Zhenhai dialect, which is evidence of a three-way contrast in tone contour. However, in disyllabic prosodic words, the tone sandhi rule deletes the tone of the second syllable and spreads the contour of the first syllable to the entire disyllabic words. This results in a

reduction of the tone contour on each syllable to a two-way contrast: level, rising or falling [9].

Therefore, we conclude that on the surface form, the markedness constraints *3[+son], *3μ, and *3T rank highest in the syllable, weight and tone tier respectively. The OT tableaux look as follows:

Tableaux 4: *Rhyme-weight-tone patterning in Zhenhai dialect.*

Base: VV, VG, VN, V?, VVN, VVG, VNN, VGG, VGN	*3[+son]	MINDIST=[+son]:1	MAXCONTRAST
a. VV, VG, VN, V?, VVN, VVG, VNN, VGG, VGN	*!		////////
b. VV, VG, VN, V?			////
c. VV, VG, V?			////!
d. VGN, V?	*!	*	///
e. VV, V?			///!
Base: μμ, μμ, μ	*3μ	MINDIST=μ: 1	MAXCONTRAST
a. μμ, μμ, μ	*!		///
b. μμ, μ	*!	*	///
c. μμ, μ			///
d. μμ			!/
e. μ			!/
Base: tt, tt, t	*3T	MINDIST=T:1	MAXCONTRAST
a. tt, tt, t	*!		///
b. tt, t	*!	*	///
c. tt, t	*!		///
d. tt, t			///
e. t			!/

As can be seen from the analysis, Zhenhai syllable-tone patterning on the surface form is like Figure 1. The reason is the high ranking of the markedness constraints that penalize super-heavy syllables and complex tone contours over those that maximize the contrast.

4. Conclusion

This study explored the syllable-tone patterning in four distinct Chinese languages by making use of the Moraic Model proposed in [1] and the perceptually-based approach in phonology: the former provides a descriptive representation of the patterns and the latter provides a functional explanation. It is found that the one-to-one patterning between weight and tone units, as illustrated in Figure 1, is commonly found in Chinese languages (MC, Shanghaiese, Cantonese and Zhenhai dialect on the surface form), whereas the one-to-many patterning between units of the two tiers, as illustrated in Figure 2, is much less common (Zhenhai dialect in citation form). The reason may be perceptually-grounded: the one-to-one patterning is the best possible way for both the syllable segments and the tones to be perceived well.

This paper only studied four Chinese languages out of the hundreds of languages and dialects in China. Further research could explore more Chinese languages by conducting phonetic experiments on both monosyllabic and multi-syllabic prosodic words, so as to provide richer evidence for the typology derived from the Moraic Model, and explore the reason why certain patterns are more common than others.

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