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Phonology-syntax interplay with respect to Tone 3 sandhi in Mandarin Chinese

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Abstract

This study investigates the phonology-syntax interplay with respect to Tone 3 sandhi in Mandarin Chinese which has been a hot topic discussed in the past several decades. There are two mainstream theories under prevalent discussion, including (i) the direct phonology-syntax mapping approach (Cheng, 1970; Liu, 1980; Kaisse, 1985) which argues that the application of Tone 3 sandhi is directly determined by the syntactic structure of the utterance on which a sequence of Tone 3 is produced, and (ii) the prosodic approach (Shih, 1986; Selkirk 1986) which suggests that the Tone 3 sandhi is only sensitive to the prosodic structure of the utterances, irrespective of the syntactic structure. The present study aims to provide empirical evidence to evaluate the two major theories of Mandarin Tone 3 sandhi and to look into the relationship between tone and syntax in Mandarin.

The first-hand speech data were recorded of ten native speakers of Mandarin, five male and five female, for frequency analysis of the F_0 contours of a sequence of Tone 3 produced on 62 syntactic units with three to five component syllables. The test units, including compound nouns, noun phrases, verb phrases, and sentences, have various types of syntactic structure. The generalized tone patterns based on the F_0 contours of the test units show that the syntactic structure plays a dominant role in determining the application of Tone 3 sandhi across the component syllables in the various types of speech units. The data confirm that Tone 3 sandhi applies cyclically from left to right and from the innermost constituent group to the outer ones as proposed in Kaisse (1985). The tone data also show a tendency in some cases to group the component syntactic constituents in bisyllabic domains, irrespective of the syntactic structure of the utterances. The semantic focus of the utterances and the syntactic distance between the component constituents may also affect the application of Tone 3 sandhi, while these factors do not play a primary role in determining the tone sandhi pattern.

To conclude, this study provides us the empirical information for a better understanding of the alignment between the prosodic domain and the syntactic structure of speech utterances in language.

Keywords: Tone 3 sandhi, phonology-syntax mapping, prosodic and syntactic structures, F_0 contours, Mandarin tones

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1 INTRODUCTION

In Mandarin, there are four lexical tones, including the high level [55] (Tone 1), the high rising [35] (Tone 2), the low falling-rising [214] (Tone 3) and the high falling [51] (Tone 4), associated with individual monosyllabic words. On a longer utterance, the lexical tones may undergo tone sandhi. In Mandarin, the Tone 3 sandhi is the most dominant case, in which a Tone 3 followed by another Tone 3 will become a sandhi Tone 2. While the Tone 3 sandhi is predictable with no exception on a bisyllabic unit, it is not the case on a longer polysyllabic unit. For instance, the bisyllabic word “老虎” (*tiger*) formed with the monosyllabic words “老” *lao3* (*old*) and “虎” *hu3* (*tiger*) is pronounced as “*lao2 hu3*” with a sandhi Tone 2 on “老”. The bisyllabic word “老虎” can also be preceded or followed by another monosyllabic word, such as “紙” *zhi3* (*paper*) or “跑” *pao3* (*run*), to form the trisyllabic units “紙老虎” (*paper tiger*) and “老虎跑” (*The tiger runs*). While “紙老虎” is pronounced as “*zhi3 lao2 hu3*” with the Tone 3 on “紙” remaining unchanged and a sandhi Tone 2 only on “老”, “老虎跑” is pronounced as “*lao2 hu2 pao3*” with a sandhi Tone 2 on both “老” and “虎”. The difference in tone pattern between the two trisyllabic units seems to be related to the syntactic structures of the two units. For “紙老虎”, it is a compound noun, formed with a preceding modifier or adjective “紙” plus the noun object “老虎”, i.e., [紙 [老虎]], where the word “虎” in the noun object undergoes Tone 3 sandhi and the sandhi Tone 2 on “虎” causes the Tone 3 on the preceding modifier “紙” remaining unchanged. As for “老虎跑”, it consists of the noun subject “老虎” plus a following verb “跑”, i.e., [[老虎] 跑], where the word “老” in the noun subject bears a sandhi Tone 2 due to the following Tone 3 on “虎” and then the word “虎” also bears a sandhi Tone 2 as it is followed by the verb “跑” associated with a Tone 3. The two cases therefore suggest that the tone sandhi domains in a long unit are determined in relation to the syntactic structure of the unit. The present study aims to look into the relationship and interplay between phonology and syntax with respect to the Tone 3 sandhi in Mandarin Chinese.

1.1 Literature Review

Cheng (1968) is an earlier phonological study of the Tone 3 sandhi in Mandarin. The author reports that the Mandarin Tone 3 maintains its full tone contour [214] only when it is produced in isolation or on the final syllable of an utterance followed by a pause. When a Tone 3 is followed by a tone other than Tone 3, it is usually produced with a low tone contour [21] without a pitch rise at the end. When two 3rd tones “*occur in an uninterrupted succession, the first changes to a second tone*” (Cheng, 1968, p.80), and this phonological phenomenon is known as Tone 3 sandhi. The author adds that when there is a sequence of Tone 3 on an utterance, the whole utterance may not necessarily be a single domain for the realization of the tone sandhi pattern of [2 2 2 ... 3].

Since Cheng’s study, the Mandarin Tone 3 sandhi has been a hot issue in the field of Chinese phonology, drawing people’s attention to the application of Tone 3 sandhi in relation to the interplay between phonology and syntax.

1.1.1 Direct phonology-syntax mapping

Cheng (1970), Liu (1980), and Kaisse (1985) argue that the sandhi domain for a sequence of Tone 3 on an utterance is determined directly by the syntactic structure of the utterance. Cheng (1970) proposes the notion of “the depth of embedding” to determine how a sequence of Tone 3 on an utterance is divided into sandhi pairs. The notion is concerned with the hierarchical syntactic structure of the utterance and the syntactic distance between the words or constituents in the utterance. In Figure 1, the syntactic structure and junctures of the sentence “老李買好酒” *Lao Li mai hao jiu* (*Old Li bought good wine*) exemplified in Cheng (1970) is shown. The syntactic distance between the words in the sentence is indicated with a number, where a larger number represents a greater syntactic distance. In the sentence, the syntactic distance or depth of embedding between the adjective “好” *hao* and the following noun “酒” *jiu* in the final NP object is 1-juncture, whereas the syntactic distance between the preceding verb “買” *mai* and the final NP object “好酒” *hao jiu* in the VP has a 2-juncture depth. It follows that in the sentence the syntactic distance between the initial NP subject “老李” *Lao Li* and the following VP “買好酒” *mai hao jiu* has a 3-juncture depth. According to Cheng (1970), the Mandarin Tone 3 sandhi obligatorily applies across the words with the syntactic distance of 1 juncture, but optionally applies across the words with the syntactic distance of a deeper juncture.

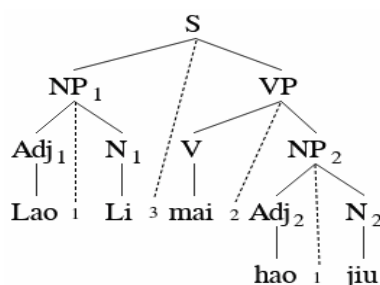


Figure 1: Syntactic structure and junctures of the sentence “老李買好酒” *Lao Li mai hao jiu* (*Old Li bought good wine*) proposed in Cheng (1970).

In Cheng (1970) as well as in Cheng (1973), it is mentioned that there is another factor, tempo, affecting the application of Mandarin Tone 3 sandhi. When the tempo increases, more 3rd tones in a sequence will undergo sandhi as illustrated in Table 1. Maximally, in a very fast speech, all the 3rd tones in a sequence, except for the last one, change to a sandhi Tone 2.

Tempo	“老” <i>Lao</i>	“李” <i>Li</i>	“買” <i>mai</i>	“好” <i>hao</i>	“酒” <i>jiu</i>
a. Adagio	[2	3]	[3]	[2	3]
b. Moderato	[2	2	3]	[2	3]
c. Allegro	[2	3]	[2	2	3]
d. Presto	[2	2	2	2	3]

Table 1: Effect of tempo on the Tone 3 sandhi pattern for the sentence “老李買好酒” *Lao Li mai hao jiu* (*Old Li bought good wine*) suggested in Cheng (1970, 1973).

Liu (1980) challenges Cheng’s (1970) theory, pointing out that the theory cannot explain why the Tone 3 sandhi is obligatory for two 3rd tones in succession on an utterance even if the syntactic distance between the two component constituents in the utterance has a deep juncture. For instance, the verb phrase “買好酒” (*have already bought wine*) is pronounced as “mai2 hao2 jiu3”. In the phrase, the verb “買” *mai* is followed by the NP object that consists of the adjective “好” *hao* plus the noun “酒” *jiu*, i.e., [買 [[好]酒]]. Therefore, while the syntactic structure between “買” and “好” is 2-juncture deeper than the 1-juncture depth between “好” and “酒”, the Tone 3 sandhi applies across “買” and “好”. Based on this example, Liu suggests that the Tone 3 sandhi in Mandarin is not cyclically applied from the most closely related part to the most distantly related ones, but in a metical way by grouping every two neighboring 3rd tones on an utterance in a pair from left to right, disregarding the syntactic structure of the utterance.

Kaisse (1985) agrees with the view of Liu (1980), but suggests a revised approach for the cyclical application of Mandarin Tone 3 sandhi by making reference to the syntactic structure of the utterance. In her approach, the Tone 3 sandhi applies to a word pair located at the edge of a larger constituent in an utterance. This is known as “Branch Condition”. As illustrated in Figure 2, the Tone 3 sandhi will apply to the word pair [a b] occurring at the final edge (in the left panel) or the initial edge (in the middle panel), but not in the medial position (in the right panel), of the utterance.

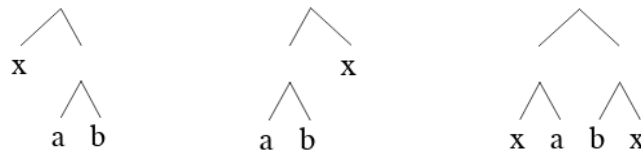


Figure 2: Kaisse’s (1985) Branch Condition for the application of Tone 3 sandhi to the word pair [a b] at the final edge (in the left panel) or the initial edge (in the middle panel), but not in the medial position (in the right panel), of the utterance.

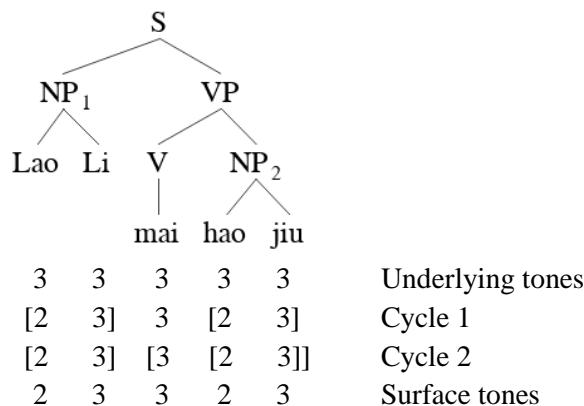


Figure 3: Cyclical application of Mandarin Tone 3 sandhi for the sentence “老李買好酒” *Lao Li mai hao jiu* (*Old Li bought good wine*) based on the Kaisse’s (1985) Branch Condition.

Based on the Branch Condition, the cyclical application of Mandarin Tone 3 sandhi to the sentence “老李買好酒” *Lao Li mai hao jiu* is illustrated in Figure 3. At the initial stage, i.e.,

Cycle 1, the Tone 3 sandhi applies to the word pairs “*Lao Li*” and “*hao jiu*” in the two NPs located at the left and right edges of the sentence. At the next stage, i.e., Cycle 2, the Tone sandhi applies again to the word pair “*mai hao*” that occurs at the edge of the VP constituent in the sentence. After Cycle 1, the word “*hao*” is associated with a sandhi Tone 2, and thus, the Tone 3 on the word “*mai*” remains unchanged at Cycle 2.

In general, both Liu (1980) and Kaisse (1985) argue that the application of Tone 3 sandhi is related to the hierarchy of the syntactic structure, rather than the syntactic categories, of the constituents in an utterance. And, in case a sequence of Tone 3 that can be pronounced with different sandhi patterns, it is due to ambiguity of the syntactic structure of the utterance, resulting in various grouping patterns for the constituents in the utterance. It follows that the same tone sandhi pattern is produced for two utterances which share the same hierarchical structure, even though the syntactic categories of the constituents in the two utterances differ. This proposal is supported by the findings of the prosodic patterns of other languages, such as Italian (Napoli and Nespors, 1979) and French (Rotenberg, 1978).

1.1.2 *Prosodic approach*

With reference to the syntactic approach presented above, Shih (1986) proposes a prosodic model to account for the application of Tone 3 sandhi in Mandarin. She suggests that the Tone 3 sandhi applies cyclically according to the prosodic structure which is derived from, but not isomorphic to, the syntactic structure of a sentence or utterance. This is based on the observation that the application of Tone 3 sandhi is not strictly guided by the syntactic structure in all cases. For instance, the sentence “狗咬好心人” (*A dog bites a kind man*) has the syntactic structure of [狗 [咬 [好心[人]]]], beginning with the noun subject “狗” *gou3* (*dog*) followed by the verb “咬” *yao3* (*bite*) and the NP object that consists of the adjective “好心” *hao3 xin1* (*kind*) plus the noun “人” *ren2* (*man*). So, according to the syntactic approach, the sentence should be pronounced as “*gou3 yao2 hao3 xin1 ren2*”, with a sandhi Tone 2 on “*yao*” and the Tone 3 on “*gou*” remaining unchanged. However, the sentence most naturally is pronounced as “*gou2 yao3 hao3 xin1 ren2*” with a sandhi Tone 2 on “*gou*” and the Tone 3 on “*yao*” remaining unchanged even followed by the Tone 3 on “*hao*”. Based on this example and other similar cases, Shih proposes a prosodic model to construct the prosodic hierarchy by grouping the constituents of an utterance into “prosodic foot”, “super-foot”, and “prosodic phrase”. In the hierarchy, “foot” is the basic unit, which is formed by two neighboring monosyllabic constituents, regardless of their syntactic categories and relationship. The details of the Foot Formation Rule (FFR) proposed in Shih (1986) are cited as follows.

Foot Formation Rule (FFR): (Shih, 1986, p.110)

- I) Foot (f) construction
 - a. IC (Immediate Constituency) link immediate constituents into disyllabic foot
 - b. DM (Duple Meter) scanning from left to right, string together unpaired syllables into binary feet, unless they branch to the opposite direction
- II) Super-foot (f') construction

Join any leftover monosyllables to a neighboring binary foot according to the direction of syntactic branching

According to Shih, the Tone 3 sandhi applies cyclically from foot level to super-foot level, and finally to prosodic phrase as illustrated in Figure 4.

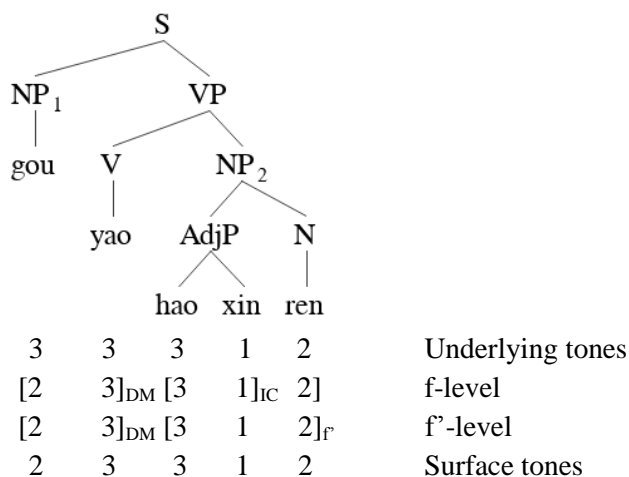


Figure 4: Application of Mandarin Tone 3 sandhi for the sentence “狗咬好心人” *gou yao hao xin ren* (A dog bites a kind man) using Shih’s (1986) prosodic model.

In view of the fact that some utterances with the same prosodic structure may be pronounced with more than one tone pattern, Shih (1986) agrees with Cheng (1970, 1973) suggesting that speech rate is an additional factor in the application of Tone 3 sandhi. She elaborates that the rate-sensitive Tone 3 sandhi rule has an adjacency threshold expressed in a given idealized time as suggested in Selkirk (1984), and the “depth of embedding” proposed in Cheng (1970) can be represented with a number of silent beats (‘x’) as presented in Figure 5. Taking the sentence “老李買好酒” *Lao Li mai hao jiu* as an example, the number of silent beats is ‘1’ between the modifier “好” *hao* (good) and the noun “酒” *jiu* (wine) in the final NP object, but ‘2’ between the verb “買” *mai* (bought) and the following NP object “好酒” *hao jiu* (good wine) and ‘3’ between the initial noun subject “老李” *Lao Li* (Old Li) and the following verb phrase “買好酒” *mai hao jiu* (bought good wine). A more number of silent beats indicates a deeper juncture. At different speech rates, a single beat takes different durations of time. Supposing the idealized time for the adjacency threshold is 200 msec, the Tone 3 sandhi applies unconstrainedly with the tone pattern of [2 2 2 2 3] at fast tempo, since the durations of all the disjunctures are below the adjacency threshold. At slow speech, the Tone 3 sandhi will only apply across the disjunctures with only one beat, where their durations are below the threshold, resulting in the tone pattern of [2 3 3 2 3].

Lao	Li	mai	hao	jiu	
x	<u>x</u>	x	<u>xxx</u>	x	<u>xx</u>
	x	x	x	x	x
	150	450	300	150	150
	100	300	200	100	100
	50	150	100	50	50
					Silent beats
					Slow speech
					Normal speech
					Fast speech

Figure 5: Rhythmic structure of the sentence “老李買好酒” *Lao Li mai hao jiu* (Old Li bought good wine) in terms of the number of silent beats (‘x’) and the corresponding hypothetical time value (in millisecond) for each rhythmic disjuncture at different tempos suggested in Shih (1986).

To sum up, Shih (1986) highlights that the Tone 3 sandhi in Mandarin is not simply determined by the syntactic structure of the utterances. She draws people's attention to the influence of prosodic structure, especially the "foot" unit, on the application of Tone 3 sandhi. Although the prosodic structure is basically derived from the syntactic one, she makes it clearly that "*there is a requirement of minimum length imposed on the prosodic structure, but not on the syntactic structure*" (Shih, 1986, p.111). Shih's prosodic approach is further developed later by Chen (2000). Chen proposes a new prosodic unit called "minimal rhythmic unit", which in general sense equivalent to Shih's "foot" unit, for the study of Mandarin prosody.

1.2 Purpose of Study

This study aims to investigate again the phonology-syntax interplay with respect to the Tone 3 sandhi in Mandarin Chinese through analysis of the polysyllabic units with various types of syntactic structures. First-hand speech data elicited from native speakers of Mandarin, which are unavailable in all the above-mentioned studies, form the basis for determining the tone sandhi patterns of the test units. The data are used to evaluate the two major approaches, the direct phonology-syntax mapping and the prosodic approach, for the application of Tone 3 sandhi in Mandarin, in an attempt to provide a better understanding of the relationship and interplay between phonology and syntax.

2 METHODOLOGY

2.1 Speakers

The present study collected speech samples from 10 native speakers of Mandarin, including 5 males and 5 females. All the speakers are young adults, aged from 20 to 25, who were born and grew up in monolingual Mandarin-speaking families in Beijing or the cities of Northern China. The speakers were studying at the City University of Hong Kong when they took part in the study. Their participation was voluntary, and consent from the speakers was received beforehand. The ten speakers were labeled as Male Speaker 1 to Male Speaker 5 and Female Speaker 1 to Female Speaker 5 for identification purposes in this report.

2.2 Test Materials

The speakers took part in an individual audio recording to produce three sets of polysyllabic units with 3, 4, or 5 component syllables associated with a sequence of Tone 3 in Mandarin. Table 2 presents the test 3-syllable units, which are classified into four types (Type 1 to Type 4) with respect to the syntactic categories and structures of the units. As can be seen, Type 1 is a noun formed with three monosyllabic words, where the noun cannot be further divided into smaller syntactic categories. Type 2 is a compound noun consisting of (a) two nouns or (b) a modifier + a noun. Type 3 is a noun phrase consisting of (a) a quantifier + a noun or (b) a noun + a modifier. Type 4 is a verb phrase consisting of (a) a verb + a noun or pronoun or (b) a resultative verb + a noun or pronoun.

Syntactic categories and structures		3-syllable units		
1. Noun		索馬里 <i>suo ma li</i> [3 3 3]		
2. Compound noun	a. Noun+Noun	水彩筆 <i>shui cai bi</i> [[3 3] 3]	展覽館 <i>zhan lan guan</i> [[3 3] 3]	演講稿 <i>yan jiang gao</i> [[3 3] 3]
	b. Modifier+Noun	女總統 <i>ny zong tong</i> [3 [3 3]]	老古董 <i>lao gu dong</i> [3 [3 3]]	鐵手柄 <i>tie shou bing</i> [3 [3 3]]
3. Noun phrase	a. Quantifier+Noun	兩桶水 <i>liang tong shui</i> [[3 3] 3]	五碗米 <i>wu wan mi</i> [[3 3] 3]	九把傘 <i>jiu ba san</i> [[3 3] 3]
	b. Noun+Modifier	水果小 <i>shuo guo xiao</i> [[3 3] 3]	古董少 <i>gu dong shao</i> [[3 3] 3]	演講短 <i>yan jiang duan</i> [[3 3] 3]
4. Verb phrase	a. Verb+(Pro)Noun	買水桶 <i>mai shui tong</i> [3 [3 3]]	打老虎 <i>da lao hu</i> [3 [3 3]]	洗水果 <i>xi shui guo</i> [3 [3 3]]
		允許我 <i>yun xu wo</i> [[3 3] 3]	打擾你 <i>da rao ni</i> [3 [3 3]]	
	b. Resultative Verb+(Pro)Noun	趕走狗 <i>gan zou gou</i> [[3 3] 3]	咬死馬 <i>yao si ma</i> [[3 3] 3]	吵醒你 <i>chao xing ni</i> [[3 3] 3]

Table 2: Test 3-syllable units in different syntactic structures associated with a sequence of Tone 3.

Table 3 presents the test 4-syllable units with four types of syntactic structures (Type 1 to Type 4) similar to those of the test 3-syllable units. As shown in Table 3, Type 1 is quadrisyllabic noun which cannot be further divided into smaller syntactic categories. Type 2 is a compound noun consisting of (a) two nouns or (b) a modifier + a noun. Type 3 is a noun phrase consisting of (a) a quantifier + a noun or (b) a noun + a modifier. Type 4 is a verb phrase consisting of (a) a verb + a noun or (b) a resultative verb + a noun.

Syntactic categories and structures		4-syllable units		
1. Noun		索馬里雅 <i>suo ma li ya</i> [3 3 3 3]		
2. Compound noun	a. Noun+Noun	展覽場館 <i>zhan lan chang guan</i> [[3 3] [3 3]]	展覽館長 <i>zhan lan guan zhang</i> [[3 3 3] 3]	
		古董展覽 <i>gu dong zhan lan</i> [[3 3] [3 3]]	水彩筆廠 <i>shui cai bi chang</i> [[3 3 3] 3]	
		演講稿紙 <i>yan jiang gao zhi</i> [[3 3] [3 3]]	老古董展 <i>lao gu dong zhan</i> [[3 3 3] 3]	
		總統府邸 <i>zong tong fu di</i> [[3 3] [3 3]]	紙雨傘館 <i>zhi yu san guan</i> [[3 3 3] 3]	
		廣場舞者 <i>guang chang wu zhe</i> [[3 3] [3 3]]		
	b. Modifier+Noun	老女總統 <i>lao ny zong tong</i> [3 [3 3 3]]	小水彩筆 <i>xiao shui cai bi</i> [3 [3 3 3]]	
		短鐵手柄 <i>duan tie shou bing</i> [3 [3 3 3]]	小展覽館 <i>xiao zhan lan guan</i> [3 [3 3 3]]	
		假老古董 <i>jia lao gu dong</i> [3 [3 3 3]]	假演講稿 <i>jia yan jiang gao</i> [3 [3 3 3]]	
	3. Noun phrase	a. Quantifier+Noun	兩桶水餃 <i>liang tong shui jiao</i> [[3 3] [3 3]]	九把雨傘 <i>jiu ba yu san</i> [[3 3] [3 3]]
			五碗米粉 <i>wu wan mi fen</i> [[3 3] [3 3]]	
b. Noun+Modifier		展覽館小 <i>zhan lan guan xiao</i> [[3 3 3] 3]	老古董少 <i>lao gu dong shao</i> [[3 3 3] 3]	
		演講稿短 <i>yan jiang gao duan</i> [[3 3 3] 3]		
4. Verb phrase	a. Verb+Noun	買水彩筆 <i>mai shui cai bi</i> [3 [3 3 3]]	打女總統 <i>da ny zong tong</i> [3 [3 3 3]]	
		找展覽館 <i>zhao zhan lan guan</i> [3 [3 3 3]]	表演舞蹈 <i>biao yan wu dao</i> [[3 3] [3 3]]	
		寫演講稿 <i>xie yan jiang gao</i> [3 [3 3 3]]	管理場館 <i>guan li chang guan</i> [[3 3] [3 3]]	
		買老古董 <i>mai lao gu dong</i> [3 [3 3 3]]	選舉組長 <i>xuan ju zu zhang</i> [[3 3] [3 3]]	
	b. Resultative Verb+Noun	趕走老虎 <i>gan zou lao hu</i> [[3 3] [3 3]]	咬死小狗 <i>yao si xiao gou</i> [[3 3] [3 3]]	
		吵醒老闆 <i>chao xing lao ban</i> [[3 3] [3 3]]		

Table 3: Test 4-syllable units in different syntactic structures associated with a sequence of Tone 3.

The test 5-syllable units presented in Table 4 are phrases or sentences with different syntactic structures. They are classified into three general types (Type 1 to Type 3). Type 1 is a verb phrase consisting of a verb + a noun. Type 2 is a noun phrase consisting of (a) a noun or (b) a compound noun followed by a modifier. Type 3 is a sentence which is further categorized into three different sub-types. Sub-type (a) consists of a subject pronoun followed by a verb and then an object noun or pronoun. Sub-type (b) consists of a subject noun followed by a verb phrase and then a pronoun. Sub-type (c) consists of a hidden subject noun followed by a double verb and then an object noun or a double object noun.

Syntactic categories and structures		5-syllable units
1. Verb phrase	Verb+Noun	改寫演講稿 <i>gai xie yan jiang gao</i> [[3 3] [3 3 3]]
2. Noun phrase	(Compound) Noun+Modifier	演講稿很短 <i>yan jiang gao hen duan</i> [[3 3 3] [3 3]]
		好水果很少 <i>hao shui guo hen shao</i> [[3 3 3] [3 3]]
3. Sentence	a. Pronoun+Verb+(Pro)Noun	我想索馬里 <i>wo xiang suo ma li</i> [[3] [3] [3 3 3]]
		請你允許我 <i>qing ni yun xu wo</i> [[3 3] [3 3] [3]]
	b. Noun+Verb Phrase+Pronoun	小美很想我 <i>xiao mei hen xiang wo</i> [[3 3] [3 3] [3]]
	c. (Noun+)Double Verb+(Double) Noun	好想買水果 <i>hao xiang mai shui guo</i> [[3 3][3] [3 3]]
		想給你水果 <i>xiang gai ni shui guo</i> [[3][3] [3][3 3]]

Table 4: Test 5-syllable units in different syntactic structures associated with a sequence of Tone 3.

In total, there are 62 polysyllabic units used for the investigation, including twenty-one 3-syllable units, thirty-three 4-syllable units, and eight 5-syllable units. All the test units are meaningful in Mandarin, and the speakers of this study are familiar with them.

2.3 Recording and Analysis

The 62 test units were numbered and presented in Chinese characters, without the Mandarin *pinyin* or IPA transcription, on a randomized list for eliciting speech samples from the speakers. Audio recordings of the speech samples were carried out in the sound-proof booth in the Phonetics Lab at the City University of Hong Kong. The speakers were instructed to read the test units on the list one by one as natural as possible at a consistent speed rate. Each speaker repeated the reading list three times, producing a total of 1,860 test tokens (62 test units x 3 times x 10 speakers) for subsequent acoustic analysis.

The speech analysis software, Praat, was used to perform F_0 analysis of the tones on the component syllables in each of the test polysyllabic units. The F_0 contours superimposed onto the narrowband spectrograms of the test units were used for determining whether the Tone 3

sandhi applies across the component syllables in the test units. It has been agreed that the Mandarin Tone 3 in general is produced with either a low falling or a low falling-rising dipping F_0 contour, and it is produced with a rising F_0 contour similar to Tone 2 when Tone 3 sandhi takes place. In the present study, it is observed that Tone 3 in actual production is produced with an F_0 contour of various shapes, including (i) high level, (ii) high rising, (iii) high falling in a slight degree, (iv) low level, (v) low falling, and (vi) low level or falling with creaky quality or breathy noise. Due to the fact that the difference between the unchanged Tone 3 and the sandhi Tone 2 lies mainly in the F_0 /pitch level, the former three of the six patterns of the F_0 contours observed for Tone 3 in actual production, i.e., (i) to (iii), are considered as the sandhi Tone 2, whereas the latter three, i.e., (iv) to (vi), are treated as the unchanged Tone 3. In Figure 6, the given diagram is an example which shows the waveform (in the upper panel) and the superimposed F_0 contours (in blue lines) onto the narrowband spectrogram (in the lower panel) for the test 4-syllable phrase “小水彩笔” *xiao shui cai bi* (*little colored pens*) produced by Male Speaker 1 in this study. As can be seen, the F_0 contours of the tones on the two medial syllables “水” *shui* and “彩” *cai* are high rising and high level, respectively, and thus the tones on these two syllables are considered as the sandhi Tone 2. As for the tones on the initial syllable “小” *xiao* and the final syllable “笔” *bi*, their F_0 contours are low level and low falling with creaky phonation, and thus the tones on these two syllables are considered as the unchanged Tone 3. It follows that the whole phrase “小水彩笔” *xiao shui cai bi* is produced with the tone pattern of [3 2 2 3].

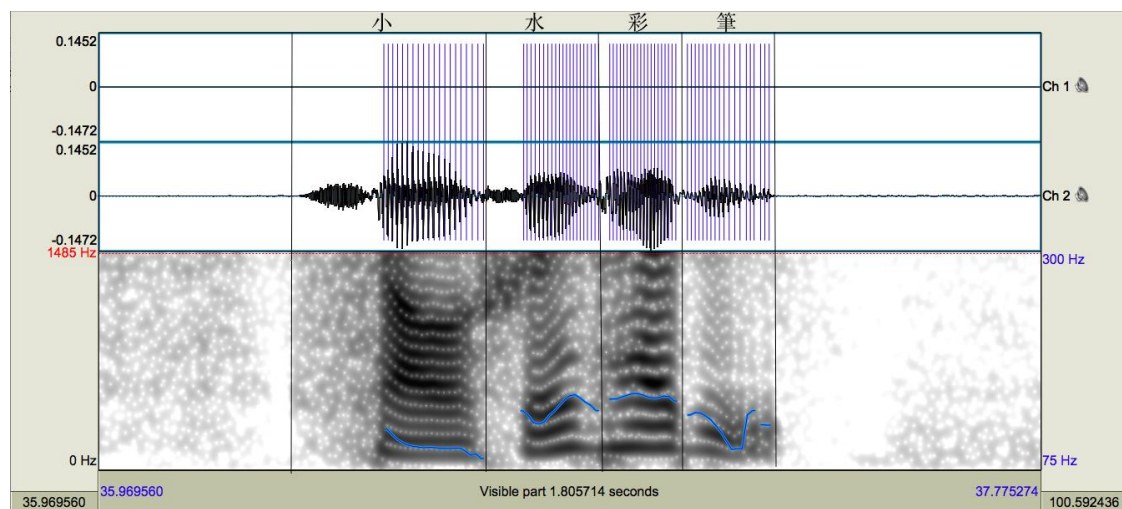


Figure 6: Waveform (in the upper panel) and the superimposed F_0 contours (in blue lines) onto the narrowband spectrogram (in the lower panel) for the test 4-syllable phrase “小水彩笔” *xiao shui cai bi* (*little colored pens*) produced by Male Speaker 1.

Based on the generalized tone patterns for the different types of test units, the application of Tone 3 sandhi with respect to the syntactic structures of the test units was described and the relationship between phonology and syntax was examined and analyzed.

3 RESULTS

This section presents the tone patterns of the three sets of test polysyllabic units, with 3, 4, or 5 component syllables, produced by the ten Mandarin speakers in this study. For each test polysyllabic unit, the tone patterns may vary among the ten speakers and/or among the three repetitions for each speaker. Thus, the percentage of occurrence for each of the tone patterns based on the total of 30 tokens (10 speakers x 3 repetitions) of a given test unit was computed and presented. The various tone patterns are then described and explained with respect to the syntactic structure of the test units and the cyclical application of Tone 3 sandhi proposed in Kaisse (1985).

3.1 3-syllable and 4-syllable Noun-headed Units

The percentages of occurrence of the tone patterns of the three general types of noun-headed units, including the nouns without internal syntactic hierarchy (Type 1), compound nouns (Type 2), and noun phrases (Type 3), are presented as follows.

3.1.1 Type 1: Nouns without internal syntactic hierarchy

The names “索馬里” (*Somali*) and “索馬里雅” (*Somalia*) are two nouns that have no internal syntactic hierarchy, with the component syllables in equidistance syntactically. According to Kaisse (1985), when this type of noun unit is associated with a sequence with Tone 3, i.e., [3 3 3 ... 3], the Tone 3 sandhi will apply cyclically from left to right over every two neighboring component syllables in the unit. As a result, the whole unit is pronounced with the tone pattern [2 2 2 ... 3], with all the 3rd tones, except for the last one, changing to a sandhi Tone 2. This prediction is not totally supported by the data on the tone patterns of the nouns “索馬里” and “索馬里雅” produced by the Mandarin speakers in this study. As presented in (1), while the noun “索馬里” is pronounced with the tone pattern [2 2 3] in the majority of cases (80%), it may also be pronounced with the tone pattern [3 2 3] in some other cases (20%). For the tone pattern [3 2 3], it seems to indicate that the Tone 3 sandhi applies from right to left, rather than left to right, as suggested in Kaisse’s (1985) proposal.

(1)	[索	馬	里]	“ <i>Somalia</i> ”
	<i>suo</i>	<i>ma</i>	<i>li</i>	
				Frequency of occurrence
Tone patterns	[2	2	3]	80%
	[3	2	3]	20%

Similarly, the noun “索馬里雅” can be pronounced with the tone patterns other than [2 2 2 3] predicted by Kaisse’s (1985) model. As shown in (2), “索馬里雅” is pronounced with the tone pattern [2 2 2 3] (43.3%) or [2 3 2 3] (40%) in similar number of cases. For the tone pattern [2 3 2 3], it indicates that the noun is divided into two bisyllabic or “foot” domains, i.e., [[索馬] [里雅]], where the Tone 3 sandhi applies within each foot domain, but not across the two foot domains. The data do not agree with the cyclical application of Tone 3 sandhi suggested in Kaisse’s (1985) proposal.

(2)	[索 馬 里 雅]	“ <i>Somalia</i> ”
	<i>suo ma li ya</i>	
		Frequency of occurrence
Tone patterns	[2 2 2 3]	43.3%
	[2 3 2 3]	40%
	[3 2 2 3]	13.3%
	[3 3 2 3]	3.3%

3.1.2 Type 2: Compound nouns

3.1.2.1 Compound nouns: Noun + Noun

In (3) to (5), the three trisyllabic compound nouns are formed with a bisyllabic noun followed by a monosyllabic noun, i.e., [[水彩] 筆] (3), [[展覽] 館] (4), and [[演講] 稿] (5). According to Kaisse’s (1985) syntactic approach, the predicted tone pattern for these three compound nouns is [2 2 3], as the Tone 3 sandhi applies cyclically from the innermost group to the outer ones. The prediction is basically supported by the data of the tone patterns for the three compound nouns in (3) to (5), as the frequency of occurrence of the tone pattern [2 2 3] is 100% for “展覽館” and “演講稿” and 90% for “水彩筆”.

(3)	[[水 彩] 筆]	“ <i>colored pens</i> ”
	<i>shui cai bi</i>	
		Frequency of occurrence
Tone patterns	[2 2 3]	90%
	[3 2 3]	10%

(4)	[[展 覽] 館]	“ <i>exhibition hall</i> ”
	<i>zhan lan guan</i>	
		Frequency of occurrence
Tone pattern	[2 2 3]	100%

(5)	[[演 講] 稿]	“ <i>speech draft</i> ”
	<i>yan jiang gao</i>	
		Frequency of occurrence
Tone pattern	[2 2 3]	100%

The quadrisyllabic compound nouns presented in (6) to (14) are also formed with two nouns. The compound nouns [[展覽] [場館]] (6), [[古董] [展覽]] (7), [[演講] [稿紙]] (8), [[總統] [府邸]] (9), and [[廣場] [舞者]] (10) consist of two bisyllabic nouns, and all of them are pronounced with the tone pattern [2 3 2 3] in the majority of cases, with the frequency of occurrence over 90%. The data clearly show that the tone pattern for these compound nouns are closely related to the syntactic structure of the compounds, where the two bisyllabic component nouns in the compounds are divided into two separate tonal domains for the application of Tone 3 sandhi.

(6)	[[展 覽] [場 館]]	“ <i>exhibition hall</i> ”
	<i>zhan lan chang guan</i>	
	Frequency of occurrence	
Tone pattern	[2 3 2 3]	100%
(7)	[[古 董] [展 覽]]	“ <i>antique exhibition</i> ”
	<i>gu dong zhan lan</i>	
	Frequency of occurrence	
Tone pattern	[2 3 2 3]	100%
(8)	[[演 講] [稿 紙]]	“ <i>speech draft</i> ”
	<i>yan jiang gao zhi</i>	
	Frequency of occurrence	
Tone patterns	[2 3 2 3]	93.3%
	[2 2 2 3]	6.7%
(9)	[[總 統] [府 邸]]	“ <i>Government House</i> ”
	<i>zong tong fu di</i>	
	Frequency of occurrence	
Tone pattern	[2 3 2 3]	100%
(10)	[[廣 場] [舞 者]]	“ <i>dancers on the square</i> ”
	<i>guang chang wu zhe</i>	
	Frequency of occurrence	
Tone pattern	[2 3 2 3]	100%
(11)	[[展 覽 館] 長]	“ <i>curator of the exhibition hall</i> ”
	<i>zhan lan guan zhang</i>	
	Frequency of occurrence	
Tone patterns	[2 3 2 3]	83.3%
	[2 2 2 3]	16.7%
(12)	[[水 彩 筆] 廠]	“ <i>factory of colored pens</i> ”
	<i>shui cai bi chang</i>	
	Frequency of occurrence	
Tone patterns	[2 3 2 3]	56.7%
	[2 2 2 3]	40%
	[3 2 2 3]	3.3%

As for the compounds [[展覽館] 長] (11) and [[水彩筆] 廠] (12), they are formed with a trisyllabic noun followed by a monosyllabic noun. The former compound [[展覽館] 長] is pronounced with the tone pattern [2 3 2 3] in over 80% of the cases, whereas the latter one [[水彩筆] 廠] is pronounced with two dominant tone patterns, [2 3 2 3] (56.7%) and [2 2 2 3] (40%). The predicted tone pattern for the two compounds is [2 2 2 3], rather than [2 3 2 3], if the Tone 3 sandhi applies cyclically from left to right and from the innermost group to the

outer ones as suggested in Kaisse (1985). The compounds pronounced with the tone pattern [2 3 2 3] indicate that there are two bisyllabic tonal domains $[[\sigma \sigma] [\sigma \sigma]]$ in the compounds, which is not in alignment with the syntactic structure of $[[\text{展覽館}] \text{長}]$ and $[[\text{水彩筆}] \text{廠}]$.

For the test units that are pronounced with more than one tone pattern, they were further examined by asking the ten Mandarin speakers in this study to comment on the acceptability of the various tone patterns for the test units. For the two quadrisyllabic compound nouns $[[\text{展覽館}] \text{長}]$ (11) and $[[\text{水彩筆}] \text{廠}]$ (12), it is told by the speakers that [2 2 2 3] is an acceptable tone pattern, while they usually pronounce these compounds with the tone pattern [2 3 2 3]. The speakers also mentioned that the optional tone patterns have no effect on the meanings of the compounds. More discussion about the discrepancy between the prosodic structure and syntactic structure of the speech units in Mandarin will be addressed in the later sessions.

There are two other quadrisyllabic compounds formed with two nouns, a trisyllabic one followed by a monosyllabic one, including $[[\text{老古董}] \text{展}]$ (13) and $[[\text{紙雨傘}] \text{館}]$ (14). The data show that the two compounds are pronounced with the tone pattern [3 2 2 3] in the majority of cases (over 90%) and an optional tone pattern [2 2 2 3] in the remaining few cases (below 10%). The dominant tone pattern [3 2 2 3] may be explained in relation to the fact that the preceding trisyllabic nouns in the two compounds can be further divided into two smaller units with a monosyllabic modifier/adjective followed by a bisyllabic noun, and thus the structures of the two compounds are $[[\text{老}[\text{古董}]] \text{展}]$ and $[[\text{紙}[\text{雨傘}]] \text{館}]$. If the Tone 3 sandhi applies cyclically from the innermost group to the outer ones as suggested in Kaisse (1985), the predicted tone pattern of the two compounds will be [3 2 2 3]. This is because in the first cycle the Tone 3 sandhi applies to the two syllables in the most inner part, resulting in a sandhi Tone 2 produced on the second syllable “古” or “雨” in the compound which causes the Tone 3 on the first syllable “老” or “紙” remaining unchanged. And, when the Tone 3 sandhi applies in the last cycle to the whole compound, a sandhi Tone 2 is produced on the third syllable “董” or “傘” due to the effect of the Tone 3 on the final syllable “展” or “館” in the compound.

(13)	$[[\text{老} \quad \text{古} \quad \text{董}] \quad \text{展}]$	<i>“old antique exhibition”</i>		
	<i>lao gu dong zhan</i>			
		Frequency of occurrence		
Tone patterns	[3 2 2 3]	96.7%		
	[2 2 2 3]	3.3%		
(14)	$[[\text{紙} \quad \text{雨} \quad \text{傘}] \quad \text{館}]$	<i>“paper-made umbrella”</i>		
	<i>zhi yu san guan</i>			
		Frequency of occurrence		
Tone patterns	[3 2 2 3]	93.3%		
	[2 2 2 3]	6.7%		

3.1.2.2 Compound nouns: Modifier + noun

The data presented in (15) to (23) are the tone patterns for the trisyllabic or quadrisyllabic compound nouns formed with a modifier plus a noun. In each case, the modifier is a monosyllabic adjective, followed by a bisyllabic or trisyllabic noun. The three trisyllabic compound nouns [女 [總統]] (15), [老 [古董]] (16), and [鐵 [手柄]] (17) are all pronounced with the tone pattern [3 2 3] in 100% of the cases. The tone pattern is related to the syntactic structure of the compounds and predicted by Kaisse's (1985) model, due to the cyclical application of Tone 3 sandhi from the innermost group to the outer ones.

(15)	[女	[總	統]]	“female president”
	<i>ny</i>	<i>zong</i>	<i>tong</i>	
				Frequency of occurrence
Tone pattern	[3	2	3]	100%
(16)	[老	[古	董]]	“old antique”
	<i>lao</i>	<i>gu</i>	<i>dong</i>	
				Frequency of occurrence
Tone pattern	[3	2	3]	100%
(17)	[鐵	[手	柄]]	“iron handlebar”
	<i>tie</i>	<i>shou</i>	<i>bing</i>	
				Frequency of occurrence
Tone pattern	[3	2	3]	100%

As for the quadrisyllabic compounds with a modifier plus a noun, the compounds [老 [女總統]] (18), [短 [鐵手柄]] (19), and [假 [老古董]] (20) are pronounced with the tone pattern [2 3 2 3] in the majority of cases. The frequency of occurrence of [2 3 2 3] is over 90% for [老 [女總統]] (93.3%) and [短 [鐵手柄]] (96.7%), while it is only 63.3% for [假 [老古董]]. According to Kaisse's model, the tone pattern for this type of compounds should be [3 2 2 3], due to the cyclical application of Tone 3 sandhi from the innermost group to the outer ones. However, the frequency of occurrence of the predicted tone pattern [3 2 2 3] is only 20% for [假 [老古董]] and below 10% for [老 [女總統]] (6.7%) and [短 [鐵手柄]] (3.3%).

(18)	[老	[女	總	統]]	“old female president”
	<i>lao</i>	<i>ny</i>	<i>zong</i>	<i>tong</i>	
					Frequency of occurrence
Tone patterns	[2	3	2	3]	93.3%
	[3	2	2	3]	6.7%
(19)	[短	[鐵	手	柄]]	“short iron”
	<i>duan</i>	<i>tie</i>	<i>shou</i>	<i>bing</i>	
					Frequency of occurrence
Tone patterns	[2	3	2	3]	96.7%
	[3	3	2	3]	3.3%

(20)	[假	[老	古	董]]	“fake old antique”
	<i>jia</i>	<i>lao</i>	<i>gu</i>	<i>dong</i>	
					Frequency of occurrence
Tone patterns	[2	3	2	3]	63.3%
	[3	2	2	3]	20%
	[3	3	2	3]	10%
	[2	3	3	3]	6.7%

For the three quadrisyllabic compounds in (18) to (20), the trisyllabic noun has a ‘1+2’ structure, where the first monosyllable is an adjective modifying the following bisyllabic noun. Thus, the syntactic structures of the three compounds can be refined as [老 [女[總統]]], [短 [鐵[手柄]]], and [假 [老[古董]]]. Given that the Tone 3 sandhi applies cyclically from the innermost group to the outer ones, the whole trisyllabic noun in the compound is pronounced with the tone pattern [3 2 3] and then the entire compound is pronounced with the tone pattern [2 3 2 3].

As for the other three quadrisyllabic compounds, [小 [水彩筆]] (21), [小 [展覽館]] (22), and [假 [演講稿]] (23), all of them are pronounced with the tone pattern [3 2 2 3] in the majority of cases (over 80%). This is related to the fact that the trisyllabic nouns in these three compounds have a ‘2+1’ structure, i.e., [[水彩]筆], [[展覽]館], and [[演講]稿]. Due to the cyclical application of Tone 3 sandhi from the innermost group to the outer ones and from left to right (Kaisse, 1985), the tone pattern is [3 2 2 3] for the compounds [小 [[水彩]筆]], [小 [[展覽]館]], and [假 [[演講]稿]].

(21)	[小	[水	彩	筆]]	“litter water color pens”
	<i>xiao</i>	<i>shui</i>	<i>cai</i>	<i>bi</i>	
					Frequency of occurrence
Tone patterns	[3	2	2	3]	86.7%
	[2	3	2	3]	6.7%
	[2	2	2	3]	3.3%
	[3	2	3	3]	3.3%
(22)	[小	[展	覽	館]]	“small exhibition hall”
	<i>xiao</i>	<i>zhan</i>	<i>lan</i>	<i>guan</i>	
					Frequency of occurrence
Tone patterns	[3	2	2	3]	96.7%
	[2	2	2	3]	3.3%
(23)	[假	[演	講	稿]]	“fake speech draft”
	<i>jia</i>	<i>yan</i>	<i>jiang</i>	<i>gao</i>	
					Frequency of occurrence
Tone patterns	[3	2	2	3]	90%
	[3	2	3	3]	10%

3.1.3 Type 3: Noun phrase

Another type of noun-headed units investigated in this study is noun phrase, which is formed with a quantifier + a noun or a noun + a modifier.

3.1.3.1 Noun phrase: Quantifier + noun

The three trisyllabic noun phrases [[兩桶] 水] (24), [[五碗] 米] (25), and [[九把] 傘] (26) consist of a bisyllabic quantifier followed by a monosyllabic noun. The bisyllabic quantifier is actually preceded by a monosyllabic numerical classifier. As shown in (24) to (26), all the three noun phrases are pronounced with the tone pattern [2 2 3] in the majority of cases (80-100%). The tone pattern is closely related to the syntactic structure of the phrases and in agreement with the cyclical application of Tone 3 sandhi proposed in Kaisse (1985).

(24)	[[兩 桶] 水]	“two buckets of water”
	<i>liang tong shui</i>	
		Frequency of occurrence
Tone patterns	[2 2 3]	80%
	[3 2 3]	20%
(25)	[[五 碗] 米]	“five bowls of rice”
	<i>wu wan mi</i>	
		Frequency of occurrence
Tone patterns	[2 2 3]	80%
	[2 3 3]	20%
(26)	[[九 把] 傘]	“nine umbrellas”
	<i>jiu ba san</i>	
		Frequency of occurrence
Tone pattern	[2 2 3]	100%

The phrases [[兩桶] 水] and [[五碗] 米] are also pronounced with the tone pattern [3 2 3] or [2 3 3] in some cases (20%). The tone pattern [3 2 3] seems to indicate that the structure of the tonal domains of the phrase is [σ [σ σ]], whereas the tone pattern [2 3 3] indicates the structure of the tonal domains as [[σ σ] σ]. The former pattern still supports the cyclical application of Tone 3 sandhi proposed by Kaisse, but the latter one does not. Nonetheless, both the tone patterns [3 2 3] and [2 3 3] are only produced in small number of cases.

The data presented below are the tone patterns for three quadrisyllabic noun phrases, [[兩桶] [水餃]] (27), [[五碗] [米粉]] (28), and [[九把] [雨傘]] (29), consisting of a bisyllabic quantifier followed by a bisyllabic noun. All the three phrases are pronounced with the tone pattern [2 3 2 3] in 100% of the cases, and the tone pattern is closely related to the syntactic structure of the phrases, supporting the cyclical application of Tone 3 sandhi proposed in Kaisse (1985).

(27)	[[兩 桶]	[水 餃]	“two buckets of dumplings”
	<i>liang tong</i>	<i>shui jiao</i>	
			Frequency of occurrence
Tone pattern	[2 3 2 3]		100%
(28)	[[五 碗]	[米 粉]	“old female president”
	<i>wu wan</i>	<i>mi fen</i>	
			Frequency of occurrence
Tone pattern	[2 3 2 3]		100%
(29)	[[九 把]	[雨 傘]	“old female president”
	<i>jiu ba</i>	<i>yu san</i>	
			Frequency of occurrence
Tone pattern	[2 3 2 3]		100%

3.1.3.2 Noun phrase: Noun + modifier

The noun phrases presented in (30) to (35) consist of a noun plus a modifier. The three trisyllabic noun phrases, [[水果] 小] (30), [[古董] 少] (31), and [[演講] 短] (32), consist of a bisyllabic noun followed by a monosyllabic adjective or modifier. They are pronounced with the tone pattern [2 2 3] in all cases, except for one token for [[水果] 小]. The tone pattern is related to the syntactic structure of the phrases and can be explained by Kaisse’s (1985) cyclical model for Tone 3 sandhi application.

(30)	[[水 果]	小]	“the fruits are small”
	<i>shui guo</i>	<i>xiao</i>	
			Frequency of occurrence
Tone patterns	[2 2 3]		96.7%
	[2 3 3]		3.3%
(31)	[[古 董]	少]	“antique is rare”
	<i>gu dong</i>	<i>shao</i>	
			Frequency of occurrence
Tone pattern	[2 2 3]		100%
(32)	[[演 講]	短]	“the speech is short”
	<i>yan jiang</i>	<i>duan</i>	
			Frequency of occurrence
Tone pattern	[2 2 3]		100%

The three quadrisyllabic noun phrases presented in (33) to (35) are formed with a trisyllabic noun plus a modifier or adjective. They are different from the trisyllabic ones in (30-32), pronounced with more than one dominant tone pattern. The phrases [[展覽館] 小] (33) and [[演講稿] 短] (34) are pronounced with either the tone pattern [2 2 2 3] or [2 3 2 3] in about half of the cases. The tone pattern [2 2 2 3] is correlated with the syntactic structure

of the phrases and can be explained by Kaisse’s cyclical model for Tone 3 sandhi. However, the tone pattern [2 3 2 3], which indicates two bisyllabic tonal domains [[σ σ] [σ σ]] occurring in the phrases, is not in alignment with the syntactic structure of [[展覽館] 小] and [[演講稿] 短].

(33)		[[展	覽	館]	小]	“the exhibition hall is small”
		<i>zhan</i>	<i>lan</i>	<i>guan</i>	<i>xiao</i>	
						Frequency of occurrence
	Tone patterns	[2	2	2	3]	56.7%
		[2	3	2	3]	43.3%
(34)		[[演	講	稿]	短]	“the speech draft is short”
		<i>yan</i>	<i>jiang</i>	<i>gao</i>	<i>duan</i>	
						Frequency of occurrence
	Tone patterns	[2	2	2	3]	50%
		[2	3	2	3]	50%
(35)		[[老	古	董]	少]	“old antique is rare”
		<i>lao</i>	<i>gu</i>	<i>dong</i>	<i>shao</i>	
						Frequency of occurrence
	Tone patterns	[3	2	2	3]	73.3%
		[2	2	2	3]	23.3%
		[2	3	2	3]	3.3%

As for the phrase [[老古董] 少] (35), it is also pronounced with two optional tone patterns in most of the cases, while one of them, the tone pattern [3 2 2 3] (73.3%), is more frequent than the other tone pattern, [2 2 2 3] (23.3%). According to the view of the ten speakers in this study, the two tone patterns have a difference in semantics. If the tone pattern [2 2 2 3] is pronounced, the whole phrase seems to have a focus on the last word or syllable “少”, emphasizing the “rarity” of the “old antique”. If the tone pattern is [3 2 2 3], the phrase has no specific focus and is naturally produced.

Both the tone patterns [3 2 2 3] and [2 2 2 3] can be explained by cyclical application of Tone 3 sandhi proposed in Kaisse (1985). The more frequent one [3 2 2 3] is related to the inner ‘1+2’ structure of the noun, i.e., [老[古董]], that consists of a monosyllabic modifier followed by a bisyllabic noun, and the tone pattern for the whole phrase [[老[古董]] 少] is due to the cyclical application of Tone 3 sandhi from the innermost part to the outer ones. As for the less frequent tone pattern [2 2 2 3], it is related to the general syntactic structure of the phrase with a trisyllabic noun plus a monosyllabic modifier, i.e., [[老古董] 少].

3.2 Type 4: 3-syllable and 4-syllable Verb-headed Units

The 3-syllable and 4-syllable test units of Type 4 re verb-headed. They include two types of verb phrases, (a) a verb followed by a noun or pronoun and (b) a resultative verb followed by a noun or pronoun.

3.2.1 Verb phrases: Verb + (pro)noun

The trisyllabic verb phrases, [買 [水桶]] (36), [打 [老虎]] (37), and [洗 [水果]] (38), consist of a monosyllabic verb followed by a bisyllabic noun. These three phrases are consistently pronounced with a single tone pattern [3 2 3] in 100% of the cases. The tone pattern is parallel to the syntactic structure of the phrases and triggered by the cyclical application for Tone 3 sandhi.

(36)	[買	[水	桶]]	“buy buckets”
	<i>mai</i>	<i>shui</i>	<i>tong</i>	
				Frequency of occurrence
Tone pattern	[3	2	3]	100%
(37)	[打	[老	虎]]	“hunt tigers”
	<i>da</i>	<i>lao</i>	<i>hu</i>	
				Frequency of occurrence
Tone pattern	[3	2	3]	100%
(38)	[洗	[水	果]]	“wash fruits”
	<i>xi</i>	<i>shui</i>	<i>guo</i>	
				Frequency of occurrence
Tone pattern	[3	2	3]	100%
(39)	[[允	許]	我]	“allow me”
	<i>yun</i>	<i>xu</i>	<i>wo</i>	
				Frequency of occurrence
Tone patterns	[2	3	3]	60%
	[2	2	3]	40%
(40)	[[打	擾]	你]	“disturb you”
	<i>da</i>	<i>rao</i>	<i>ni</i>	
				Frequency of occurrence
Tone patterns	[2	2	3]	67.7%
	[2	3	3]	33.3%

As for the other two trisyllabic verb phrases, [[允許] 我] (39) and [打擾] [你]] (40), with a bisyllabic verb followed by a monosyllabic pronoun, both of them are pronounced with two tone patterns [2 3 3] and [2 2 3]. For [[允許] 我], the frequency of occurrence is slightly larger for the tone pattern [2 3 3] (60%) than the tone pattern [2 2 3] (40%). As for [打擾] [你]], the situation is reversed, with the tone pattern [2 2 3] being more frequently pronounced (67.7%) than the tone pattern [2 3 3] (33.3%). The difference between the two patterns is in the tone on the second syllable as the unchanged Tone 3 or a sandhi Tone 2. The tone pattern [2 2 3] corresponds to the syntactic structure of the two phrases [[允許] 我] and [打擾] [你]], but the tone pattern [2 3 3] does not. The latter one [2 3 3] seems to indicate that the verb and the following pronoun are treated as separate units or tonal domains in the

phrase, so that the Tone 3 on the second syllable remains unchanged before the Tone 3 on the final syllable.

There are also eight quadrisyllabic verb phrases formed with a verb plus a noun. Five of them, [買 [水彩筆]] (41), [找 [展覽館]] (42), [寫 [演講稿]] (43), [買 [老古董]] (44), and [打 [女總統]] (45), consist of a monosyllabic verb followed by a trisyllabic noun. These five verb phrases are divided into two groups with respect to their tone patterns. For the phrases [買 [水彩筆]] (41), [找 [展覽館]] (42), and [寫 [演講稿]] (43), their dominant tone pattern is [3 2 2 3], with the frequency of occurrence over 86% or even more so 100% for the latter two phrases. The tone pattern [3 2 2 3] is related to the syntactic structure of the three phrases and derived due to the cyclical application of Tone 3 sandhi from the innermost part to the outer ones.

(41)	[買	[水	彩	筆]]	“buy colored pens”
	<i>mai</i>	<i>shui</i>	<i>cai</i>	<i>bi</i>	
					Frequency of occurrence
Tone patterns	[3	2	2	3]	86.7%
	[3	2	3	3]	10%
	[2	2	2	3]	3.3%
(42)	[找	[展	覽	館]]	“search for the exhibition hall”
	<i>zhao</i>	<i>zhan</i>	<i>lan</i>	<i>guan</i>	
					Frequency of occurrence
Tone pattern	[3	2	2	3]	100%
(43)	[寫	[演	講	稿]]	“write the speech draft”
	<i>xie</i>	<i>yan</i>	<i>jiang</i>	<i>gao</i>	
					Frequency of occurrence
Tone pattern	[3	2	2	3]	100%

As for the other two phrases [買 [老古董]] (44) and [打 [女總統]] (45), their dominant tone pattern is [2 3 2 3], produced in 73.3% and 93.3% of the cases, respectively. These two phrases differ from those three phrases in (41-43) in the inner structure of the noun object contained in the verb phrase. In the verb phrases [買 [水彩筆]] (41), [找 [展覽館]] (42), and [寫 [演講稿]], the trisyllabic nouns have a ‘2+1’ structure consisting of a bisyllabic noun followed by a monosyllabic noun, and thus the structure of the three phrases can be refined as [買 [[水彩]筆]], [找 [[展覽]館]], and [寫 [[演講]稿]]. As for the verb phrases [買 [老古董]] (44) and [打 [女總統]] (45), the trisyllabic nouns have a ‘1+2’ structure, formed with a monosyllabic modifier followed by a bisyllabic noun, and thus the refined structures of the two phrases are [買 [老[古董]]] and [打 [女[總統]]]. According to Kaisse’s cyclical model, Tone 3 sandhi applies from innermost group to the outer ones, so that the dominant tone pattern is [3 2 2 3] for the phrases in (41-43), but [2 3 2 3] for the phrases in (44-45).

(44)	[買	[老	古	董]]	“ <i>buy old antique</i> ”
	<i>mai</i>	<i>lao</i>	<i>gu</i>	<i>dong</i>	
					Frequency of occurrence
Tone patterns	[2	3	2	3]	73.3%
	[3	3	2	3]	16.7%
	[3	2	2	3]	10%
(45)	[打	[女	總	統]]	“ <i>attack the female president</i> ”
	<i>da</i>	<i>ny</i>	<i>zong</i>	<i>tong</i>	
					Frequency of occurrence
Tone patterns	[2	3	2	3]	93.3%
	[3	3	2	3]	6.7%

For the five phrases (41-45) mentioned above, some of them may be pronounced with other tone patterns. In all these cases, the frequency of occurrence of the tone patterns is not more than 10%. The exception is the phrase [買 [老古董]] (44) which is pronounced with the tone pattern [3 3 2 3] in 16.7% of the cases. The tone pattern [3 3 2 3] indicates that the verb “買” and the following noun “老古董” in the phrase are separated into two tonal domains, so that the Tone 3 on the preceding verb remains unchanged before the Tone 3 on the first syllable of the following noun.

The three other quadrisyllabic verb phrases presented in (46) to (48) are formed with a bisyllabic verb followed by a bisyllabic noun. As can be seen, all these three phrases [[表演] [舞蹈]] (46), [[管理] [場館]] (47), and [[選舉] [組長]] (48) are pronounced with a single tone pattern [2 3 2 3] without exception. The tone pattern is closely related to the syntactic structure of the phrases.

(46)	[[表	演]	[舞	蹈]]	“ <i>perform dancing</i> ”
	<i>biao</i>	<i>yan</i>	<i>wu</i>	<i>dao</i>	
					Frequency of occurrence
Tone pattern	[2	3	2	3]	100%
(47)	[[管	理]	[場	館]]	“ <i>take charge of the exhibition hall</i> ”
	<i>biao</i>	<i>yan</i>	<i>wu</i>	<i>dao</i>	
					Frequency of occurrence
Tone pattern	[2	3	2	3]	100%
(48)	[[選	舉]	[組	長]]	“ <i>elect the leader</i> ”
	<i>xuan</i>	<i>ju</i>	<i>zu</i>	<i>zhang</i>	
					Frequency of occurrence
Tone pattern	[2	3	2	3]	100%

3.2.2 Verb phrases: Resultative verb + (pro)noun

There is another set of trisyllabic and quadrisyllabic verb phrases, which consists of a resultative verb plus a noun or pronoun. The trisyllabic ones [[趕走] 狗] (49), [[咬死] 馬]

(50), and [[吵醒] 你] (51) presented below consist of a bisyllabic resultative verb followed by a monosyllabic noun or pronoun. As can be seen, all these three phrases are pronounced with the tone pattern [2 2 3] in the majority of the cases (over 90%), where the tone pattern is closely related to the syntactic structure of the phrases and triggered by the cyclical application of Tone 3 sandhi from the innermost part to the outer ones.

(49)		[[趕	走]	狗]	“drive away the dog”
		<i>gan</i>	<i>zou</i>	<i>gou</i>	
					Frequency of occurrence
	Tone patterns	[2	2	3]	93.3%
		[3	2	3]	6.7%
(50)		[[咬	死]	馬]	“bite the horse to death”
		<i>yao</i>	<i>si</i>	<i>ma</i>	
					Frequency of occurrence
	Tone patterns	[2	2	3]	96.7%
		[3	2	3]	3.3%
(51)		[[吵	醒]	你]	“wake you up”
		<i>chao</i>	<i>xing</i>	<i>ni</i>	
					Frequency of occurrence
	Tone pattern	[2	2	3]	100%

The quadrisyllabic phrases [[趕走] [老虎]] (52), [[吵醒] [老闆]] (53), and [[咬死] [小狗]] (54) consist of a bisyllabic resultative verb followed by a bisyllabic noun. These three phrases are consistently pronounced with the tone pattern [2 3 2 3] in 100% of the cases, and the tone pattern is perfectly in alignment with the syntactic structure of the phrases.

(52)		[[趕	走]	[老	虎]]	“drive away the tiger”
		<i>gan</i>	<i>zou</i>	<i>lao</i>	<i>hu</i>	
						Frequency of occurrence
	Tone pattern	[2	3	2	3]	100%
(53)		[[吵	醒]	[老	闆]]	“wake up the boss”
		<i>chao</i>	<i>xing</i>	<i>lao</i>	<i>ban</i>	
						Frequency of occurrence
	Tone pattern	[2	3	2	3]	100%
(54)		[[咬	死]	[小	狗]]	“bite the little dog to death”
		<i>yao</i>	<i>si</i>	<i>xiao</i>	<i>gou</i>	
						Frequency of occurrence
	Tone pattern	[2	3	2	3]	100%

3.3 5-syllable Units

Aside from the 3-syllable and 4-syllable ones, there are eight noun-headed or verb-headed units with 5 syllable components. The 5-syllable units are classified into three general types with respect to their internal syntactic structure, including verb phrases (Type 1), noun phrases (Type 2), and sentences with a noun subject + a verb + a noun object (Type 3). The results of each type are as follows.

3.3.1 Type 1: Verb phrase

In (55), the 5-syllable verb phrase [[改寫] [演講稿]] consists of a bisyllabic verb followed by a trisyllabic noun, and it is pronounced consistently with a single tone pattern [2 3 2 2 3] by all the speakers. The tone pattern is closely related to the syntactic structure of the phrase, with the preceding verb and the following noun separated into two tonal domains. Due to the cyclical application of Tone 3 sandhi from the innermost unit to the outer ones, the whole phrase is pronounced with the tone pattern [2 3 2 2 3]

(55)	[[改 寫]	[演 講 稿]]	“ <i>revise the speech draft</i> ”
	<i>gai xie</i>	<i>yan jiang gao</i>	
			Frequency of occurrence
Tone pattern	[2 3	2 2 3]	100%

3.3.2 Type 2: Noun phrase

The second type of the 5-syllable units includes two noun phrases as presented in (56) and (57). The noun phrase [[演講稿] [很短]] in (56) consists of the trisyllabic noun followed by a bisyllabic modifier with a monosyllabic adverb “很” plus a monosyllabic adjective “短”. This noun phrase is pronounced consistently with a single tone pattern in all the cases. The tone pattern is [2 2 3 2 3], indicating the parallel between the prosodic structure [[σ σ σ] [σ σ]] and the syntactic structure of the phrase [[演講稿] [很短]].

(56)	[[演 講 稿]	[很 短]]	“ <i>revise the speech draft</i> ”
	<i>yan jiang gao</i>	<i>hen duan</i>	
			Frequency of occurrence
Tone pattern	[2 2	3 2 3]	100%

The noun phrase [[好水果] [很少]] in (57) also consists of a trisyllabic noun followed by a modifier with the adverb “很” plus the adjective “少”. Different from the case in (56), the trisyllabic noun in the phrase in (57) is a compound formed with a monosyllabic modifier followed by a bisyllabic noun and thus the syntactic structure of the whole phrase in (57) can be refined as [[好[水果]] [很少]]. Another difference between the phrases in (56) and (57) is in the tone pattern. The latter is pronounced with the tone pattern [3 2 3 2 3] in the majority of cases (96.7%), which is in relation to the syntactic structure of the phrase [[好[水果]] [很少]]. Due to the cyclical application of Tone 3 sandhi from the innermost group to the outer one, the tone pattern of the noun phrase in (57) is [3 2 3 2 3].

(57)	[[好	水	果]	[很	少]]	“good fruits are rare”
	<i>hao</i>	<i>shui</i>	<i>guo</i>	<i>hen</i>	<i>shao</i>	
						Frequency of occurrence
Tone patterns	[3	2	3	2	3]	96.7%
	[3	2	2	2	3]	3.3%

3.3.3 Type 3: Sentence

The third type of the 5-syllable units in this study is the S-V-O sentence consisting of a noun subject followed by a verb and then a noun object. The sentence in (58), [[我] [想] [索馬里]], consists of a pronoun subject followed by a monosyllabic verb and then a trisyllabic noun object. It is pronounced with 4 different tone patterns, with the tone pattern [2 3 2 2 3] being the most frequent one (76.7%) as compared to the other patterns. The tone pattern [2 3 2 2 3] is a predicted one due to the cyclical application of Tone 3 sandhi across and within the constituents in the sentence. Due to the fact that the trisyllabic object noun [索馬里] in the sentence can be optionally pronounced with the tone pattern [2 2 3] and [3 2 3] (See Section 3.1.1), the sentence in (58) is also pronounced with the tone pattern [2 2 3 2 3] in 16.7% of the cases. In general, the prosodic structure of the sentence [[我] [想] [索馬里]] for Tone 3 sandhi is in alignment with the syntactic structure of the sentence.

(58)	[[我]	[想]	[索	馬	里]]	“I miss Somali.”
	<i>wo</i>	<i>xiang</i>	<i>suo</i>	<i>ma</i>	<i>li</i>	
						Frequency of occurrence
Tone patterns	[2	3	2	2	3]	76.7%
	[2	2	3	2	3]	16.7%
	[2	3	3	2	3]	3.3%
	[2	2	2	2	3]	3.3%

In (59), the sentence [[請你] [允許] [我]] consists of a pronoun subject followed by a verb phrase with a bisyllabic verb plus a pronoun object. It is pronounced with two tone patterns: [2 3 2 3 3] (80%) and [2 3 2 2 3] (20%). Both the tone patterns show close relationship between the prosodic structure and syntactic structure of the sentence. The difference between the two tone patterns is concerned with the verb phrase in the sentence whether it has one or two tonal domains. Based on the fact that the dominant tone pattern of the sentence [[請你] [允許] [我]] is [2 3 2 3 3], the preceding verb and the following pronoun in a verb phrase tend to be separated into two tonal domains, without applying Tone 3 sandhi across the two tonal domains in the phrase.

(59)	[[請	你]	[允	許]	[我]]	“Please allow me.”
	<i>qing</i>	<i>ni</i>	<i>yun</i>	<i>xu</i>	<i>wo</i>	
						Frequency of occurrence
Tone patterns	[2	3	2	3	3]	80%
	[2	3	2	2	3]	20%

The sentence [[小美] [很想我]] (60) consists of the bisyllabic noun subject “小美” followed by a verb phrase with the monosyllabic adverb “很” plus the monosyllabic verb “想” and the monosyllabic object pronoun “我”. This sentence is pronounced with three tone patterns, [2 3 2 2 3] (46.7%), [2 2 3 2 3] (36.7%), and [2 3 2 3 3] (16.7%), where the frequency of occurrence of each tone pattern is below 50%. The variation in tone pattern for the sentence seems to be related to the variation in the grouping of the three constituents, adverb - verb - pronoun, in the verb phrase of the sentence. For the tone pattern [2 3 2 2 3], the three constituents in the verb phrase form a single domain, corresponding to the general syntactic structure of [[小美] [很想我]]. As for the tone pattern [2 2 3 2 3], the sentence is structured as [[小美] [[很][想我]]], separating the adverb from the verb phrase into two domains. As for the tone pattern [2 3 2 3 3], the syntactic structure of the sentence becomes [[小美] [[很想][我]]], separating the final pronoun from the verb phrase and blocking the application of Tone 3 sandhi across the constituents in the verb phrase.

(60)	[[小	美]	[很	想	我]]	“ <i>Xiao Mei misses me very much.</i> ”
	<i>xiao</i>	<i>mei</i>	<i>hen</i>	<i>xiang</i>	<i>wo</i>	
						Frequency of occurrence
Tone patterns	[2	3	2	2	3]	46.6%
	[2	2	3	2	3]	36.7%
	[2	3	2	3	3]	16.7%

The last two sentences presented in (61) and (62) consist of a hidden pronoun subject followed by a double verb and then a noun or a double noun. The sentence [[好想][買] [水果]] (61) is pronounced with two tone patterns, [2 2 3 2 3] (73.3%) and [2 3 3 2 3] (26.7%). The former tone pattern [2 2 3 2 3] indicates that the double verb forms a single domain, separating from the final bisyllabic noun, i.e., [[好想買] [水果]]. As for the tone pattern [2 3 3 2 3], it may be interpreted by structuring the sentence as (i) [[好想] [[買][水果]], with the first verb separating from the verb phrase and becoming a modifier of the verb phrase, or (ii) [[好想][買] [水果]], with the two verbs separated into two domains. In any case, no application of Tone 3 sandhi applies across the two verbs.

(61)	[[好	想]	[買]	[水	果]]	“(I) want to buy fruits very much.”
	<i>hao</i>	<i>xiang</i>	<i>mai</i>	<i>shui</i>	<i>guo</i>	
						Frequency of occurrence
Tone patterns	[2	2	3	2	3]	73.3%
	[2	3	3	2	3]	26.7%

As for the sentence [[想][給] [你][水果]] (62), it consists of a double verb and a double object with a pronoun followed by a noun. The sentence is pronounced with two tone patterns, with [3 2 3 2 3] in the majority of the cases (86.7%) and [2 3 3 2 3] in the other cases (13.3%). Both the tone patterns indicate that the double object has two domains, separating the preceding pronoun “你” from the following noun “水果”. The difference between the two tone patterns lies mainly in the double verb. For the tone pattern [3 2 3 2 3], the first verb is

separated and being a modifier of the verb phrase, i.e., [[想] [[給][你][水果]]]. As for the tone pattern [2 3 3 2 3], the double verb may form a single or two domains, i.e., [[想給] [你][水果]] or [[想][給] [你][水果]], where in any case no Tone 3 sandhi applies across the double verb and the following double noun.

(62)	[[想]	[給]	[你]	[水	果]]	“(I want to give you fruits.”
	<i>xiang</i>	<i>gei</i>	<i>ni</i>	<i>shui</i>	<i>guo</i>	
						Frequency of occurrence
Tone patterns	[3	2	3	2	3]	86.7%
	[2	3	3	2	3]	13.3%

4 DISCUSSION

In this section, discussion is made based on the data of the tone patterns of the three sets of test units, 3-syllable, 4-syllable, and 5-syllable units, presented in the previous section, with respect to the direct tone-syntax mapping approach and the cyclical application of Tone 3 sandhi proposed in Kaisse (1985).

4.1 3-syllable Units

Among the three sets of test units in different length, the tone patterns of the 3-syllable units are simple, which are closely related to the syntactic structure of the test units. In general, the trisyllabic units are pronounced with one of the two tone patterns, [2 2 3] and [3 2 3]. For the noun-headed unit without internal syntactic hierarchy, like the ethnic name “索馬里” (*Somali*), the whole unit forms a single domain for Tone 3 sandhi, i.e., [σ σ σ], resulting in the tone pattern [2 2 3] by applying the sandhi rule cyclically from left to right. In some tokens, it is found that the noun “索馬里” may also be pronounced with the tone pattern [3 2 3], challenging that the direction of the cyclical application of Tone 3 sandhi is not necessarily from left to right. In view of the fact that there is only a single trisyllabic name “索馬里” tested in the study and this name is not commonly spoken in daily life by Mandarin speakers, more data are required to come up with the general tone pattern for this type of noun.

As for the other trisyllabic units, including compound nouns, noun phrases, and verb phrases, consisting of more than one component constituents, the tone pattern is basically mapping to the syntactic structure of the units. For those with a ‘2+1’ structure, i.e., a bisyllabic component + a monosyllabic component, such as [[水彩]筆], [[兩桶]水], [[水果]小], and [[趕走]狗], the tone pattern is [2 2 3]. As for those with a ‘1+2’ structure, i.e., a monosyllabic component + a bisyllabic one, such as [女[總統]] and [買[水桶]], the tone pattern is [3 2 3]. In both cases, the Tone 3 sandhi applies cyclically from the innermost group to the outer ones. The exceptional case is only the verb phrases consisting of a bisyllabic verb followed by a monosyllabic pronoun, such as [[允許]我] and [打擾[你]]. In this case, other than the tone pattern [2 2 3] which is usually pronounced for the trisyllabic units with a ‘2+1’ structure, the tone pattern [2 3 3] is also found. The tone pattern [2 3 3] seems to indicate that the verb and the following pronoun in a verb phrase are not the close constituents, resulting in absence of the Tone 3 sandhi application across the two constituents. According to the view of the native Mandarin speakers in this study, the tone pattern [2 3 3] is more acceptable for verb phrase (VP) than noun phrase (NP), supporting that the distance between a verb and a following noun in VP is relatively large as compared to the distance between the constituents, such as an adjective and a noun, in NP.

4.2 4-syllable Units

As for the 4-syllable or quadrisyllabic units, they can be pronounced with various types of tone patterns due to the complication or ambiguity of the syntactic structure of the units. The general structure types of the quadrisyllabic units in this study include ‘2+2’, ‘1+3’, and ‘3+1’. But, for the component constituents in the units, the bisyllabic ones may be formed

with a ‘1+1’ structure and the trisyllabic ones with a ‘2+1’ or ‘1+2’ structure. There is also a single quadrisyllabic country name “索馬里雅” (*Somalia*) without internal syntactic structure. For this name, it can be pronounced with various types of tone patterns, with [2 2 2 3] and [2 3 2 3] as the two dominant ones, but none of them has the frequency of occurrence over 50%. The data thus indicate that the Mandarin speakers are not very sure of the tone pattern for this name or the name has two optional tone patterns indeed. Nonetheless, the two tone patterns for “索馬里雅” show that the name may form a single domain or two bisyllabic domains for tone sandhi. Thus, more data are required to come up with the tone pattern for this type of quadrisyllabic unit. As for the other three types of quadrisyllabic units with the structures of ‘2+2’, ‘1+3’, and ‘3+1’, the generalizations are presented as follows.

4.2.1 ‘2+2’ structure

The quadrisyllabic units with a ‘2+2’ structure include compound nouns, noun phrases, and verb phrases, such as the compounds [[展覽][場館]] and [[古董][展覽]] with two bisyllabic component nouns, the noun phrases [[兩桶][水餃]] and [[五碗][米粉]] with a bisyllabic quantifier followed by a bisyllabic noun, and the verb phrases [[表演][舞蹈]] and [[趕走][老虎]] with a bisyllabic verb or resultative verb followed by a bisyllabic noun. For all these quadrisyllabic units, they are pronounced with the tone pattern [2 3 2 3], where the tone pattern is directly mapping to the syntactic structure of the units and predicted by Kaisse’s (1985) cyclical approach for Mandarin Tone 3 sandhi.

4.2.2 ‘1+3’ structure

The units with a ‘1+3’ structure include the quadrisyllabic compounds and verb phrases, such as [老[女總統]], [小[水彩筆]], [找[展覽館]], and [買[老古董]], with a monosyllabic modifier or verb followed by a trisyllabic noun. These units can be further divided into ‘1+[1+2]’ and ‘1+[2+1]’, because the inner structure of the trisyllabic noun in the units may be ‘1+2’, e.g., [女[總統]] and [老[古董]], or ‘2+1’, e.g., [[水彩筆] and [[展覽]館]. In the majority of cases (over 86%), the quadrisyllabic units with a ‘1+[2+1]’ structure, such as [小[[水彩筆]] and [找[[展覽]館]], are pronounced with the tone pattern [3 2 2 3] which is directly mapping to the syntactic structure of the units. Due to the cyclical application of Tone 3 sandhi from the innermost group to the outer ones, the tone pattern for the trisyllabic noun in the phrase is [2 2 3], preceded by an unchanged Tone 3 on the initial syllable in the phrase. The tone pattern [3 2 2 3] in fact also maps to the general ‘1+3’ ([σ [σ σ σ]]) structure of the quadrisyllabic phrase. Due to the cyclical application of Tone 3 sandhi from left to right over the component syllables in the following trisyllabic noun, a sandhi Tone 2 is pronounced on the first and the second component syllable in the noun and the Tone 3 on the initial syllable in the phrase remains unchanged.

As for the quadrisyllabic units with a ‘1+[1+2]’ structure, such as [老[女總統]] and [買[老[古董]]], they are pronounced with the tone pattern [2 3 2 3] with the frequency of occurrence over 86%, except for two units. The tone pattern [2 3 2 3] for this type of quadrisyllabic units is also closely related to the syntactic structure of the units. Due to the cyclical application of Tone 3 sandhi from the innermost group to the outer ones, the

following trisyllabic noun in the phrase is pronounced with the tone pattern [3 2 3] which causes the tone on the initial syllable in the phrase to become a sandhi Tone 2. As for the two exceptional quadrisyllabic units with a ‘1+[1+2]’ structure, including a noun phrase [假 [老 [古董]]] and a verb phrase [買 [老 [古董]]], they are also pronounced with the tone pattern [2 3 2 3] in about 60-70% of the cases. In the other cases, they are pronounced with the tone patterns [3 2 2 3] and [3 3 2 3]. For the tone pattern [3 2 2 3], it maps to the general ‘1+3’ ([σ [σ σ σ]]) structure of the phrase. Due to the cyclical application of Tone 3 sandhi from left to right, only the two medial syllables in the phrase have a sandhi Tone 2. For this case, Shen (1994) argues that the inner structure of the trisyllabic noun in the phrase is ‘1+2’, i.e., [老 [古董]], and in the noun the derivation of a sandhi Tone 2 on the first syllable is triggered by the sandhi Tone 2 on the second syllable after the first cycle of Tone 3 sandhi. Shen’s argument however has not explained why the Tone 3 on the initial syllable in the phrase remains unchanged before a sandhi Tone 2 on the first syllable in the following noun. Wang (2000) has another argument for the case. The author suggests that the sandhi tone pattern for some polysyllabic units has been lexicalized, irrespective of the internal syntactic structure of the units. However, the trisyllabic noun [老古董] in question is consistently pronounced with the tone pattern [3 2 3], rather than [2 2 3], by all the Mandarin speakers in the present study. Thus, the lexicalized tone pattern for [老古董] should be [3 2 3], but not the tone pattern [2 2 3] for the noun pronounced in the phrases [假 [老古董]] and [買 [老古董]]. Furthermore, the two quadrisyllabic units in question can also be pronounced with the tone pattern [3 3 2 3] in some cases, also indicating that the dominant tone pattern for [老古董] is [3 2 3]. The problem for the two phrases with the tone pattern [3 3 2 3] mainly lies in the unchanged Tone 3 on the initial syllable in the phrase. In view of the fact that the tone pattern [3 3 2 3] is more frequent for the verb phrase [買 [老 [古董]]] (16.7%) than the noun phrase [假 [老 [古董]]] (10%), it may be considered that the reason is due to a larger syntactic distance between a verb and a noun in VPs than between a modifier adjective and a noun in NPs. This argument is supported by the intuition of the Mandarin speakers in this study. All of the ten Mandarin speakers agree that the tone pattern [3 3 2 3] is more acceptable for verb phrases than noun phrases.

4.2.3 ‘3+1’ structure

In the present study, there are eight quadrisyllabic units with the general ‘3+1’ structure, including four compound nouns, [[展覽館] 長], [[水彩筆] 廠], [[老古董] 展], and [[紙雨傘] 館], and three noun phrases, [[展覽館] 小], [[演講稿] 短], and [[老古董] 少]. The predicted tone pattern for these units is [2 2 2 3], due to the cyclical application of Tone 3 sandhi from left to right and from the innermost group to the outer ones. However, the obtained data in this study show that the tone pattern [2 2 2 3] is not the dominant one for the compound nouns, where the frequency of occurrence is below 50% for [[展覽館] 長] and [[水彩筆] 廠] and in particular small below 10% for [[老古董] 展] and [[紙雨傘] 館]. For the former two compounds, the more dominant tone pattern is [2 3 2 3], which is not in alignment with the syntactic structure of the compounds. The tone pattern [2 3 2 3] indicates that the compounds have the two bisyllabic tonal domains, i.e., [[σ σ] [σ σ]], supporting

Shih's (1986) prosodic approach. Shih proposes the binary or "foot" construction to group every two neighboring monosyllabic units in an utterance to form bisyllabic tonal domains. According to the view of the Mandarin speakers in the present study, both the tone patterns [2 2 2 3] and [2 3 2 3] can be pronounced for the compounds in question. And 50% of the speakers think that there is a slight difference in the semantic focus between the two patterns. For instance, the compound noun [[展覽館] 長] (*curator of the exhibition hall*) pronounced with the tone pattern [2 2 2 3] seems to have a focus on the second noun "長" (*curator*). If the tone pattern [2 3 2 3] is pronounced, the focus seems to shift to the first noun "展覽館" (*exhibition hall*). In this sense, semantic focus is also a factor in determining the realization of Tone 3 sandhi.

As for the other two quadrisyllabic compounds [[老古董] 展] and [[紙雨傘] 館], their dominant tone pattern is [3 2 2 3] (over 90%), and they are never pronounced with the tone pattern [2 3 2 3] by the Mandarin speakers in the present study. The tone pattern [3 2 2 3] seems to be in relation to the '1+2' structure of the preceding trisyllabic noun in the compound. So, if the structure of the two quadrisyllabic compounds is refined as [[σ[σ σ]] σ], the tone pattern [3 2 2 3] is derived by applying Tone 3 sandhi cyclically from the innermost group to the outer ones.

As for the three quadrisyllabic noun phrases, [[展覽館] 小], [[演講稿] 短], and [[老古董] 少], the former two are pronounced with each of two tone patterns, [2 2 2 3] and [2 3 2 3], in about 50% of the cases, where [2 2 2 3] is predicted by Kaisse's (1985) direct phonology-syntax mapping approach and [2 3 2 3] is predicted by Shih's (1986) foot construction prosodic approach. As for the phrase [[老古董] 少], it is pronounced with the tone pattern [2 2 2 3] or [2 3 2 3] in about 25% of the cases only, and more dominantly it is pronounced with the tone pattern [3 2 2 3] (over 70%). The dominant pattern seems to map to the '1+2' structure of the noun in the phrase, i.e., [老[古董]]. Due to the cyclical application of Tone 3 from the innermost group to the outer ones, the entire phrase [[老[古董]] 少] is pronounced with the tone pattern [3 2 2 3].

4.3 5-syllable units

For the 5-syllable units, the tone patterns of the verb phrases or noun phrases are basically in alignment with the syntactic structure of the phrases. For instance, the verb phrase [[改寫] [演講稿]] and the noun phrase [[演講稿] [很短]] are only pronounced with a single tone pattern, [2 3 2 2 3] or [2 2 3 2 3] respectively. As for the noun phrase [[好水果] [很少]], it is pronounced with the tone pattern [3 2 3 2 3] in over 96% of the cases, where the tone pattern [3 2 3] for the preceding noun in the phrase is related to the inner '2+1' structure of the noun, i.e., [好[水果]].

As for the 5-syllable sentences, they are pronounced with various tone patterns, due to the variability of the grouping of the component constituents in the sentences. The exception is only the sentence [[我] [想] [索馬里]]. It is pronounced with two dominant tone patterns, [2 3 2 2 3] (76.7%) and [2 2 3 2 3] (16.7%), which is in relation to the fact that the noun "索馬里" can be pronounced with the tone pattern [2 2 3] or [3 2 3]. The more frequent tone

pattern for “索馬里” is [2 2 3], and thus the whole sentence is more frequently pronounced with the tone pattern [2 3 2 2 3] than [2 2 3 2 3]. In any case, the tone patterns [2 3 2 2 3] and [2 2 3 2 3] are in alignment with the syntactic structure of the sentence and derived due to the cyclical application of Tone 3 sandhi from left to right and from the innermost group to the outer ones.

For the other sentences, they are pronounced with various tone patterns due to the variability of the grouping of component constituents in the sentences. For instance, the sentence [[小美] [很想] [我]] is pronounced with three tone patterns, [2 3 2 2 3] (46.6%), [2 2 3 2 3] (36.7%), and [2 3 2 3 3] (16.7%), depending on the grouping of the constituents “很”, “想”, and “我” in the sentence. The constituents can be grouped together to form a single domain, and then the sentence [[小美] [很想我]] is pronounced with the tone pattern [2 3 2 2 3]. The constituents can also be separated to form two domains, and then the sentence is pronounced with the tone pattern [2 2 3 2 3] with the structure [[小美] [很[想我]]], but pronounced with the tone pattern [2 3 2 3 3] with the structure [[小美] [[很想]我]]. In the latter case, no Tone 3 sandhi applies across the syllables “想” and “我”. This may be related to a large syntactic distance between a verb and a noun as observed in some of the 3-syllable and 4-syllable verb phrases in this study presented earlier.

Similarly, the sentence [[請你] [允許] [我]] is pronounced with the tone pattern [2 3 2 3 3] (80%) more frequent than the tone pattern [2 3 2 2 3] (20%). This also indicates the verb “允許” and the noun “我” are distant constituents in the sentence. As for the sentences [[好想][買] [水果]] and [[想][給] [你][水果]], distant relationship is also observed for the double verb. The sentence [[好想][買] [水果]] is pronounced with the tone pattern [2 2 3 2 3] (73.3%) or [2 3 3 2 3] (26.7%). In the latter case, no Tone 3 sandhi applies across the two verbs “想” and “買”. As for the sentence [[想][給] [你][水果]], it is pronounced with the tone pattern [3 2 3 2 3] (86.7%) or [2 3 3 2 3] (13.3%). In the former case, the tone pattern indicates the two verbs “想” and “給” are separated into two domains, so that the Tone 3 on the first verb “想” remains unchanged. In the latter case, there is no Tone 3 sandhi across the verb “給” and the following noun “你”.

5 CONCLUSION

This study has presented the tone patterns of various types of polysyllabic syntactic units, including compound nouns, noun phrases, verb phrases, and sentences, in Mandarin Chinese. The tone patterns are generalized based on the first-hand speech data collected from ten native Mandarin speakers, male and female. The data demonstrate that the tone patterns are basically related to the syntactic structure of the utterances, supporting the direct phonology-syntax mapping approach and the cyclical application of tone sandhi from left to right and from the innermost constituent group to the outer ones as proposed in Kaisse (1985). Some of the utterances may be pronounced with various types of tone pattern, which is mainly due to the variability in the structure or grouping of the constituents in the utterances.

Some tone patterns show a tendency to group the component constituents in bisyllabic domains, irrespective of the syntactic structure of the utterances, similar to the binary foot construction in the prosodic model proposed by Shih (1986). There are some other observable factors, such as the semantic focus and the syntactic distance, that may also affect the application of Tone 3 sandhi. Nonetheless, these factors do not play a dominant or primary role in determining the tone sandhi pattern for the utterances in Mandarin.

To conclude, this study has provided empirical evidence on the interplay between phonology and syntax with respect to the Tone 3 sandhi in Mandarin Chinese. The obtained data substantiate the description of the direct phonology-syntax mapping approach proposed in the previous studies on the Mandarin Tone 3 sandhi. The findings of this study also provide us a better understanding of the alignment between the prosodic domain and the syntactic structure of speech utterances in language.

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7 APPENDIX

Number of tokens for the different tone patterns associated with the test 3-syllable units produced by five male (M1 to M5) and five female (F1 to F5) Mandarin speakers.

		M1	M2	M3	M4	M5	F1	F2	F3	F4	F5	Total
1. 索馬里 <i>suo ma li</i>	[2 2 3]	3	3	3			3	3	3	3	3	24
	[3 2 3]				3	3						6
2a. 水彩筆 <i>shui cai bi</i>	[2 2 3]	3	3	3		3	3	3	3	3	3	27
	[3 2 3]				3							3
展覽館 <i>zhan lan guan</i>	[2 2 3]	3	3	3	3	3	3	3	3	3	3	30
演講稿 <i>yan jiang gao</i>	[2 2 3]	3	3	3	3	3	3	3	3	3	3	30
2b. 女總統 <i>ny zong tong</i>	[3 2 3]	3	3	3	3	3	3	3	3	3	3	30
老古董 <i>lao gu dong</i>	[3 2 3]	3	3	3	3	3	3	3	3	3	3	30
鐵手柄 <i>tie shou bing</i>	[3 2 3]	3	3	3	3	3	3	3	3	3	3	30
3a. 兩桶水 <i>liang tong shui</i>	[2 2 3]	2		3	3	3	1	3	3	3	3	24
	[3 2 3]	1	3				2					6
五碗米 <i>wu wan mi</i>	[2 2 3]	3	1	3	1	3	3	1	3	3	3	24
	[2 3 3]		2		2			2				6
九把傘 <i>jiu ba san</i>	[2 2 3]	3	3	3	3	3	3	3	3	3	3	30
3b. 水果小 <i>shui guo shao</i>	[2 2 3]	3	3	3	2	3	3	3	3	3	3	29
	[2 3 3]				1							1
古董少 <i>gu dong shao</i>	[2 2 3]	3	3	3	3	3	3	3	3	3	3	30
演講短 <i>yan jiang duan</i>	[2 2 3]	3	3	3	3	3	3	3	3	3	3	30
4a. 買水桶 <i>mai shui tong</i>	[3 2 3]	3	3	3	3	3	3	3	3	3	3	30
打老虎 <i>da lao hu</i>	[3 2 3]	3	3	3	3	3	3	3	3	3	3	30
洗水果 <i>xi shui guo</i>	[3 2 3]	3	3	3	3	3	3	3	3	3	3	30
4b. 允許我 <i>yun xu wo</i>	[2 2 3]		2	2			2	3		2	1	12
	[2 3 3]	3	1	1	3	3	1		3	1	2	18
打擾你 <i>da rao ni</i>	[2 2 3]		3	2		2	2	3	3	3	2	20
	[2 3 3]	3		1	3	1	1				1	10
4c. 趕走狗 <i>gan zou gou</i>	[2 2 3]	3	3	3	2	3	3	3	3	3	2	28
	[3 2 3]				1						1	1
咬死馬 <i>yao si ma</i>	[2 2 3]	3	3	3	3	3	3	3	3	3	2	29
	[3 2 3]										1	1
吵醒你 <i>chao xing ni</i>	[2 2 3]	3	3	3	3	3	3	3	2	3	3	29

Number of tokens for the different tone patterns associated with the test 4-syllable units produced by five male (M1 to M5) and five female (F1 to F5) Mandarin speakers.

		M1	M2	M3	M4	M5	F1	F2	F3	F4	F5	Total
1. 索馬里雅 <i>suo ma li ya</i>	[2 3 2 3]	2		1			3	3	3			12
	[3 3 2 3]	1										1
	[2 2 2 3]		3	2	1	1				3	3	13
	[3 2 2 3]				2	2						4
2a. 展覽場館 <i>zhan lan chang guan</i>	[2 3 2 3]	1	3	3	3	3	3	3	3	3	3	30
	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
古董展覽 <i>gu dong zhan lan</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
	[2 2 2 3]									2		2
演講稿紙 <i>yan jiang gao zhi</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	28
	[2 2 2 3]									2		2
總統府邸 <i>zong tong fu di</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
廣場舞者 <i>guang chang wu zhe</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
	[2 3 2 3]	3	3	2	3	3	2	3		3	3	25
展覽館長 <i>zhan lan guan zhang</i>	[2 2 2 3]			1			1		3			5
	[2 3 2 3]	3	2	2	2	3	2	1		1	1	17
水彩筆廠 <i>shui cai bi chang</i>	[2 2 2 3]		1	1	1		1	1	3	2	2	12
	[3 2 2 3]							1				1
	[2 3 2 3]	3	3	3	3	3	2	3	3	3	3	29
老古董展 <i>lao gu dong zhan</i>	[2 2 2 3]						1					1
	[3 2 2 3]	3	3	3	3	3	3	3	1	3	3	27
紙雨傘館 <i>zhi yu san guan</i>	[2 2 2 3]								2			2
	[2 3 2 3]	3	3	3	3	3	3	3	3	3	1	28
2b. 老女總統 <i>lao ny zong tong</i>	[3 2 2 3]										2	2
	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	29
短鐵手柄 <i>duan tie shou bing</i>	[3 3 2 3]									1		1
	[2 3 2 3]	3	3	2	3		2	3	3			19
假老古董 <i>jia lao gu dong</i>	[3 2 2 3]					3					3	6
	[3 3 2 3]									3		3
	[2 3 3 3]			1			1					2
	[2 3 2 3]									2		2
小水彩筆 <i>xiao shui cai bi</i>	[3 2 2 3]	2	3	3	3	3	2	3	3	1	3	26
	[3 2 3 3]	1										1
	[2 2 2 3]						1					1
	[3 2 2 3]	3	3	3	2	3	3	3	3	3	3	29
小展覽館 <i>xiao zhan lan guan</i>	[2 2 2 3]				1							1
	[3 2 2 3]	2	3	3	3	3	3	3	1	3	3	27
假演講稿 <i>jia yan jiang gao</i>	[3 2 3 3]	1							2			3
	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
3a. 兩桶水餃 <i>liang tong shui jiao</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
五碗米粉 <i>wu wan mi fen</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
九把雨傘 <i>jiu ba yu san</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30

3b. 展覽館小 <i>zhan lan guan xiao</i>	[2 3 2 3]	3			2	2	2	2	1		1	13
	[2 2 2 3]		3	3	1	1	1	1	2	3	2	17
演講稿短 <i>yan jiang gao duan</i>	[2 3 2 3]	3	2		3	2	1	1		2	1	15
	[2 2 2 3]		1	3		1	2	2	3	1	2	15
老古董少 <i>lao gu dong shao</i>	[3 2 2 3]	1	2	3	3	1		3	3	3	3	22
	[2 2 2 3]	2	1			2	2					7
	[2 3 2 3]						1					1
4a. 買水彩筆 <i>mai shui cai bi</i>	[3 2 2 3]	3	3	2	3	3	1	3	2	3	3	26
	[2 2 2 3]						1					1
	[3 2 3 3]			1			1		1			3
找展覽館 <i>zhao zhan lan guan</i>	[3 2 2 3]	3	3	3	3	3	3	3	3	3	3	30
寫演講稿 <i>xie yan jiang gao</i>	[3 2 2 3]	3	3	3	3	3	3	3	3	3	3	30
買老古董 <i>mai lao gu dong</i>	[2 3 2 3]	3	3	2	3	3	2	2	3	1		22
	[3 3 2 3]			1				1		2	1	5
	[3 2 2 3]						1				2	3
打女總統 <i>da ny zong tong</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	1	28
	[3 3 2 3]										2	2
表演舞蹈 <i>bian yan wu dao</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
管理場館 <i>guan li chang guan</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
選舉組長 <i>xuan ju zu zhang</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
4b. 趕走老虎 <i>gan zou lao hu</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
吵醒老闆 <i>chao xing lao ban</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
咬死小狗 <i>yao si xiao gou</i>	[2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30

Number of tokens for the different tone patterns associated with the test 5-syllable units produced by five male (M1 to M5) and five female (F1 to F5) Mandarin speakers.

		M1	M2	M3	M4	M5	F1	F2	F3	F4	F5	Total
1. 改寫演講稿 <i>gai xie yan jiang gao</i>	[2 3 2 2 3]	3	3	3	3	3	3	3	3	3	3	30
2. 演講稿很短 <i>yan jiang gao hen duan</i>	[2 2 3 2 3]	3	3	3	3	3	3	3	3	3	3	30
好水果很少 <i>hao shui guo hen shao</i>	[3 2 3 2 3]	3	3	3	3	3	3	3	3	3	2	29
	[3 2 2 2 3]										1	1
3a. 我想索馬里 <i>wo xiang suo ma li</i>	[2 3 2 2 3]	3	3	3			3	2	3	3	3	23
	[2 3 3 2 3]				1							1
	[2 2 3 2 3]				2	3						5
	[2 2 2 2 3]							1				1
請你允許我 <i>qing ni yun xu wo</i>	[2 3 2 2 3]		2	1				1		1	1	6
	[2 3 2 3 3]	3	1	2	3	3	3	2	3	2	2	24
3b. 小美很想我 <i>xiao mei hen xiang wo</i>	[2 3 2 2 3]	1				2	3	2	2	2	2	14
	[2 3 2 3 3]	1				1			1	1	1	5
	[2 2 3 2 3]	1	3	3	3			1				11
3c. 好想買水果 <i>hao xiang mai shui guo</i>	[2 2 3 2 3]	2	3	3	1	3	2	2		3	3	22
	[2 3 3 2 3]	1			2		1	1	3			8
想給你水果 <i>xiang gei ni shui guo</i>	[3 2 3 2 3]	3	3	3	3	3	3	3	3	2	1	27
	[2 3 3 2 3]									1	2	3