Appeared in *Phonology* 11:1-24, 1994

Syllabic Weight and Syllabic Duration: A Correlation between Phonology and Phonetics[*]

San Duanmu
University of Michigan

This paper explores a correlation between phonology and phonetics. It first reviews a phonological analysis that proposes that all full Mandarin rimes are heavy and that all Shanghai rimes are underlyingly light. Then it reports a small phonetic experiment that attempts to determine whether there is a phonetic correlate for the phonological claim. Four Mandarin speakers and five Shanghai speakers were recorded, each reading five sentences four times at normal speed. Average syllable durations were determined. It as found that the average syllable duration in Mandarin was 215 ms and that in Shanghai was 162 ms. Statistics show that the durational difference is significant. The result thus agrees with the phonological analysis. Implications and limitations of the present study will be discussed.

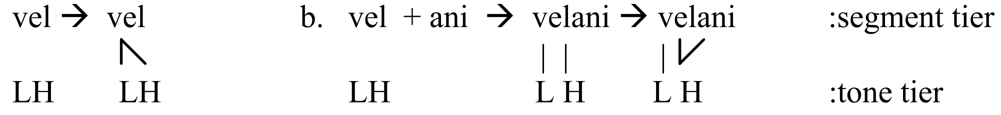
1. The Problem

We begin with a well-known difference between African tone languages and Asian tone languages. In African tone languages, "contour tones" (e.g., rise, fall, fall-rise, rise-fall) are analyzable as a sequence of level tones, in that a rise is LH (low and high), a fall is HL, a fall-rise is HLH, and so on (Leben 1973, Williams 1976, Goldsmith 1976, and many subsequent works in multi-tiered phonology). For example, consider the following data from the African language Margi (Williams 1976).

(1) Margi (ˇ = rise, ` = low, ´ = high)

a. věl	b. vèlání
jump	jump-cause
'to jump'	'to make jump'

(2)



The word *vel* 'to jump' has a rising tone. In the word *velani* 'to make jump', the first syllable has a low tone, and the second and third syllables have a high tone. It is independently known that the suffix *ani* has no underlying tones, in that its surface tones are dependent on the preceding morpheme. The high tones on *ani* in (1b), then, must have come from *vel*, which indeed changes from a rise in isolation to a L before *ani*. The multi-tiered analysis of (1) is given in (2). In this analysis, *vel* has two underlying tones, L and H. When *vel* occurs alone, both tones are linked to it, giving a rise. When *vel* is followed by the toneless *ani*, L remains on the first syllable, but H is shifted to the second syllable and then spread to the third, giving the surface pattern [L H H]. Williams's analysis is supported by a broad body of evidence in African tone languages and has become the standard approach in multi-tiered phonology.

In Asian tone languages, however, a contour tone does not usually split into a sequence of level tones, even if there are toneless syllables that could share it. Consider the following examples in Mandarin Chinese

(3) Mandarin (ˇ = rise, ` = low, ´ = high)[1]

a.	mǒ	b.	mǒ le (*mò lé)
	grind		grind ASPECT
	'to grind'		'ground'

```
(4)   a.  mo  → mo              b.  mo  +  le  →  *mo le
               |\                                   |  |
          LH      LH                LH               L  H
```

The syllable *mǒ* 'to grind' has a rise when said alone, shown in (3a). One would expect, in view of the African facts, that the rise would split into L and H when *mǒ* is followed by a toneless morpheme. However, this does not happen. When *mǒ* is followed by the toneless Aspect marker *le*, as in (3b), it still carries a rise, and *le* remains toneless. In other words, the analysis in (4), which parallels (2), makes the wrong prediction.

According to the popular view, the contrast between Margi and Mandarin is due to a fundamental difference between African contour tones and Asian contour tones. African contour tones are made of sequences of level tones, but Asian contour tones are single units (Pike 1948, Wang 1967, Gandour and Fromkin 1978, Chen 1986, 1992, Ladefoged 1982, Yip 1989, 1992, Bao 1990, 1992, Chan 1991, among others).[2] The reason for the difference is not explained, though, but is assumed to be a matter of typological or parametric variation.

It has been noted, however, that some Chinese languages, in particular those in the Wu dialect family, behave just like African languages and unlike other Chinese languages. The best known case is Shanghai (also called "New Shanghai" or "Mainstream Shanghai" by Xu et al 1988). Consider the Shanghai cognates of Mandarin (3), given below

(5) Shanghai (ˇ = rise, ` = low, ´ = high)

a.	mǔ	b.	mù léʔ
	grind		grind ASPECT
	'to grind'		'ground'

```
(6)   a.  mu  → mu              b.  mu  +  leʔ  →  mu  leʔ
               |\                                   |    |
          LH      LH                LH                L  H
```

As in Mandarin, the Shanghai syllable *mu* 'to grind' has a rise when said alone.

But unlike Mandarin, when *mu* is followed by the toneless Aspect marker *leʔ* in (5b), the rise splits into a L on the first syllable and a H on the second (see Jin 1986, Yip 1980, Selkirk and Shen 1990, Duanmu 1993, among others). The analysis of (5) is given in (6), which is exactly what we saw in (2) for the African language Margi.

The behavior of Shanghai tones raises a question for the popular view, namely, what makes Shanghai, and some of its neighboring dialects, behave like African languages and unlike other Chinese languages? In addition, *mo* in Mandarin and *mu* in Shanghai are cognate words, whose present tones are derived from the same historical tone. What sound change led to a contour tone unit in one and a cluster of L and H in the other? The popular view provides no satisfactory answers to such questions.[3]

2. The phonological analysis

Duanmu 1993 proposed a phonological solution to the above puzzle. The central claim is that, in Chinese languages, there is a systematic correlation between the tone pattern of a language and its syllable structures. Once the syllabic difference is recognized, the tonal difference follows from standard metrical and tonal principles.

In languages whose tone patterns resemble Shanghai (hereafter S-languages), such as Wuxi, Suzhou, Old Shanghai, Danyang and Nantong, there are no diphthongs. In addition, in what are traditionally transcribed as CVC syllables, there are no minimal pairs in which codas are contrastive. Specifically, the only possible codas in an S-language are [n ŋ ʔ], or in some transcriptions, just [ŋ ʔ]. For transcriptions that distinguish [n ŋ], [ŋ] is used after back vowels and [n] after other vowels. [ʔ] occurs with glottalized vowels only. Phonologically, therefore, one may consider [Vn] and [Vŋ] as underlyingly a nasalized V, and [Vʔ] as underlyingly a glottalized V.

As an example, let us consider Shanghai. According to Zhu et al (1986), there are five rimes with a nasal coda [əŋ iŋ yŋ oŋ aŋ] (ignoring pre-nuclear glides, which are of no concern for us here. See Duanmu 1993 for more discussion). In Xu et al 1988, however, the same rimes are transcribed as [ən in yn oŋ ã]. In addition, Xu et al (1988: 73) point out that [ən in yn oŋ] "are often pronounced as [ə̃ ĩ ỹ õ]". Clearly, the nasal coda is not a contrastive segment. One can, therefore, analyze the five nasal rimes as [ə̃ ĩ ỹ õ] underlyingly. The fact that Xu et al use a nasal coda for non-low vowels but nasalization for the low vowel may be due to the fact that high vowels are less likely to be perceived as nasalized than low vowels (Whalen and Beddor 1989). Shanghai also has a few rimes traditionally written as [Vʔ], where the [V] is glottalized and the [ʔ] has neither closure nor duration in non-final positions (Chao 1928, 1967, Xu et al 1988). Therefore [Vʔ] can be analyzed as a glottalized [V] underlyingly. In summary, all Shanghai syllables can be analyzed as having no underlying coda position.

In languages whose tone patterns resemble Mandarin (hereafter M-languages), such as Cantonese, Taiwanese, Hakka and the majority of other Chinese languages (as well as some Southeast Asian tone languages, such as Thai), there are diphthongs.[4] In addition, codas are contrastive, such as [in] and [iŋ] in Mandarin, or [ap] and [ak] in Cantonese, Taiwanese and Hakka.

The following summary shows the systematic correlation between rime type and tone sandhi patterns.

(7)	Coda contrast	Diphthongs	Tone sandhi
Cantonese[5]	+	+	M
Xiamen	+	+	M
Meixian	+	+	M
Mandarin	+	+	M
Fuzhou	+	+	M
--			
New Shanghai	-	-	S
Old Shanghai	-	-	S
Suzhou	-	-	S
Danyang	-	-	S
Shaoxing	-	-	S
Nantong	-	-	S

All languages above the line have contrastive codas and diphthongs. All languages below the line have lack contrastive codas and diphthongs. In addition, all languages above the line behave like Mandarin in regard to tone sandhi (M-languages), namely, when full syllables occur together, they largely keep their own tones and contour tones do not split into level tones.[6] In contrast, all languages below the line behave like Shanghai in regard to tone sandhi (S-languages), namely, only the underlying tones of the domain[7] initial syllable are kept and contour tones can split into level tones (cf. Zee and Maddieson 1979, Xu et al 1988, Selkirk and Shen 1990 for New Shanghai; Sherard 1972, Shen 1981a-b, 1982, Xu et al 1988 for Old Shanghai; Ye 1979, Xie 1982, Qian and Shi 1983 for Suzhou; Lü 1947, 1980 for Danyang; Wang 1959, Wang 1991 for Shaoxing; Ao 1993 for Nantong).[8]

A further distinction between M-languages and S-languages is that in M-languages, there is a clear contrast between "full" syllables (which are the majority) and "weak" syllables (which are the minority); full syllables are longer and have greater stress, while weak syllables are shorter and lack stress (as well as lacking tone). In Mandarin, for example, all full syllables have comparable rime durations, which are about twice the average duration of a weak rime (Woo 1969, Lin and Yan 1988). In S-languages, however, the distinction between full and weak syllables is not obvious.[9]

The systematic correlation between syllabic structure and the pattern of tone sandhi has been completely ignored in previous studies. In the current framework of metrical and tonal phonology, however, the syllabic difference between M-languages and S-languages can lead to their tonal difference without additional assumptions. In M-languages, all full syllables are heavy (with two rime slots or moraic units), hence they may each carry two tones (as in many African languages where the tone bearing unit is the moraic unit rather than the entire syllable). In S-languages, all syllables are light underlyingly (with one rime slot or moraic unit), hence they may each carry just one tone; a syllable may carry two tones only in a monosyllabic domain, where it will be lengthened, due to a well-known metrical constraint against a "degenerate" foot (i.e., a foot consisting of a light syllable, cf. McCarthy and Prince 1990, Prince 1992, among others).

According to this analysis, the full representations of (3) and (5) are as follows, where [’] indicates glottalization.

(8) Mandarin
a. moo → moo 'to grind' b. moo + le → moo le 'ground'
| | | |
LH LH LH LH
grind + ASPECT

(9) Shanghai
a. mu → muu 'to grind' b. mu + le’ → mu le’ 'ground'
| | | |
LH LH LH L H
grind + ASPECT

In (8), *moo* is a full syllable and is heavy, with a long vowel; *le* is a weak syllable and is light, with a short vowel. Thus, *moo* will take two tones whether or not there is a toneless syllable after it, as proposed by Woo (1969).[10] Unlike Margi, H in (8b) does not further spread to the second syllable *le*, because multiple spreading is optional across languages (Pulleyblank 1986). In (9), *mu* is underlyingly light, with a short vowel. It will lengthen in a monosyllabic domain and take two tones, as in (9a), or remain light and take just one tone when another syllable follows in the same domain, as in (9b). The syllable *le'* in (9b) is also light. For reasons discussed earlier, [’] is used here to indicate glottalization of the vowel, instead of a separate sound [ʔ]. For further arguments, see Duanmu 1993.

The syllabic difference between S-languages and M-languages is an independent fact that has to be acknowledged in any study. In the analysis of Duanmu 1993, once the syllabic difference is recognized, the tonal difference follows. The typological difference in contour tone structures, as assumed by the popular view, is both unnecessary and unwarranted.

3. A phonetic prediction?

The phonological analysis above raises a question that serves as the basis of the present study, namely, to what extent is a difference in phonological syllabic weight realized as a difference in phonetic syllabic duration? In other words, if in M-languages, most syllables are heavy, and in S-languages, all syllables are light, will M-languages be spoken at a slower rate than S-languages, in terms of syllables per unit time? More specifically, according to Duanmu 1993, a full syllable in an M-language has three segment slots CVX, and all underlying syllables in an S-language have two segment slots CV. Ideally, would one expect the average syllable duration in an S-language to be about 2/3 of that in an M-language?

A priori, this prediction may or may not follow from the phonological analysis.

For it to follow, it ought to be the case that both Mandarin and Shanghai are "segment timed".[11] While there have been suggestions for "stress timed" languages and "syllable timed" languages (e.g., Pike 1945: 34-35, Abercrombie 1964, Catford 1977, Lehiste 1977, and many subsequent studies), proposals for segment timed languages are few (but see Pointon 1980 for Spanish and Balasubramanian 1980 for Tamil). If both Shanghai and Mandarin are syllable timed, or both are stress timed, or if either is syllable timed or stress timed and the other is not, then their difference in phonological syllabic weight may not correlate with phonetic syllabic duration in any straightforward manner.

On the other hand, in a given language, segment timing must play a role. For example, a long vowel is longer than a short vowel in all languages in which length is contrastive, and a geminate consonant is longer than a non-geminate consonant in languages like Arabic and Japanese. This indicates that at least within the same language, phonological segment slots do have durational correlates phonetically. Nevertheless, it is not clear whether this language-internal correlation can translate into systematic cross-linguistic difference in the length of heavy and light rimes. Indeed, speakers of the same language may vary considerably in their average syllable durations, or for that matter, in their average segment durations (see, for example, Beckman and Edwards 1990), and this makes a cross-linguistic comparisons all the more complicated.

Durational data from existing literature provide partial confirmation of the phonological analysis. For example, Howie (1976) found that all full Mandarin syllables have similar durations, on the order of 300 ms.[12] Similar results are reported by Lin and Yan (1988), who also found that all full Mandarin syllables have similar durations. In addition, Lin and Yan found that the average duration of a full Mandarin rime is about twice that of a "weak" rime. An earlier work by Woo (1969) showed similar results as that of Lin and Yan. Such phonetic studies support the phonological analysis that all full Mandarin syllables are heavy, namely, with two segment slots in the rime. They also show that phonetic correlates can be found, at least in some cases, for the phonological analysis.

While durational studies on Mandarin provide fairly consistent results, similar studies on Shanghai are nearly non-existent. The only relevant work, to my knowledge, is Zee and Maddieson (1979). If the phonological analysis in section 2 is correct, all Shanghai syllables are light, and one would expect their average duration to be shorter than that of full Mandarin syllables. However, according to Zee and Maddieson (1979: 101), the average duration of a Shanghai syllable is also about 300 ms (excluding glottalized syllables, which were found to be shorter). In other words, the average duration of a Shanghai syllable is similar to that of a full Mandarin syllable, showing no phonetic indication of their purported difference in phonological weight.

However, these phonetic results should be interpreted with caution. First, the study of Zee and Maddieson was based on just one speaker (Zee and Maddieson 1979: 96). Second, and more importantly, the environments in which the target syllables occurred were not properly controlled. For example, in Howie's study of Mandarin, the target syllable was read in the following carrier sentence (Howie p. 40, 147)

(10)	zhe-ge X	zi,	shi	Lao	Li	xie	de
	this	character	be	Old	Li	write	Asp

'This character X was written by Old Li.'

In Zee and Maddieson's study of Shanghai, the target syllable was also read in a carrier sentence, shown in (10).

(11)	ŋu	do’	X	pa’	nõ	tʰĩ
	I	read		give	you	listen

'I read X for you to listen.'

At first sight, (10) and (11) appear to be comparable environments. But a closer look shows that they are not. In (10), the target syllable does not lie at a major syntactic boundary, since it and the following syllable *zi* together form an NP. In contrast, in (11), the target syllable is the object NP by itself, and it lies before a major syntactic boundary, namely, that between the object NP and the adverbial clause. Phonologically, therefore, the target syllable in (11) forms a monosyllabic domain (for the formation of phonological domains, cf. Selkirk and Shen 1990, Duanmu 1993); consequently, it will lengthen to a heavy syllable. It is natural therefore that the target syllables in Mandarin (10) and that in Shanghai (11) have similar durations, since both syllables are heavy; the former is heavy underlyingly, while the latter is heavy though lengthening in a monosyllabic domain. It is interesting to note that if (10) is used for Shanghai, the target syllable will form a domain with the following syllable *zi*.

It remains to be shown, therefore, whether in multi-syllabic domains, the average syllable in an S-language is shorter than an average full syllable in an M-language. For this purpose, a pilot study was carried out.

4. Methodology

An experiment was designed to examine the average syllable durations in Mandarin and Shanghai. In order to reduce extraneous influences on duration, such as monosyllabic domains, semantic ambiguities, and syntactic boundaries, the following conditions were taken into consideration in designing the test material. First, there be only full syllables in Mandarin and there be no monosyllabic domains. This is to ensure that all Mandarin syllables are heavy and all Shanghai syllables light (i.e., not to be lengthened in monosyllabic domains). Second, the test materials contain no syntactic or semantic ambiguities. This is to avoid the need for the speaker to intentionally exaggerate certain syntactic boundaries (cf. Lehiste 1973). Third, the test materials be presented in Chinese characters, so that the speakers would not be influenced by phonetic transcriptions in regard to the syllabic structure. Fourth, the test materials be natural and each piece not be too long, so that no hesitations or pauses would arise within an utterance. Finally, the test materials be syntactically and semantically identical in both languages, as well as having the same number of syllables. Any durational effect from syntactic boundaries and metrical structures (cf. Klatt 1975, Beckman and Edwards 1990) should therefore be similar for both Mandarin and Shanghai speakers and thus not obscure their durational difference arising from syllabic structures.

The test material for each language consisted of five simple sentences, with a total of 55 syllables. They are shown below, where both the phonetic transcription and the Chinese characters are given.[13]

(12) Test sentences for Mandarin

A: 昨天晚上下過大雪
tsʷo-tʲʰan wan-ʂaŋ ça kʷo ta çʷe (8 syllables)
yesterday night fall ASPECT big snow
'There was heavy snow last night.'

B: 他到紐約去過五十三次
tʰa tau nʲu-ye tçʷʰü kʷo wu-ʂʐ-san tsʰz (10 syllables)
he to New-York go ASPECT fifty-three times
'He has been to New York fifty-three times.'

C: 王醫生住在中山公園附近
waŋ ji-ʂəŋ ʈʂu-tsai ʈʂoŋ-ʂan koŋ-yan fu-tçin (11 syllables)
Wang doctor live-in Zhongshan park vicinity
'Dr Wang lives in the vicinity of Zhongshan Park.'

D: 這家百貨公司不賣雙門冰箱
ʈʂɤ-tça pai-hʷo-koŋ-sz pu mai ʂʷaŋ-men piŋ-çaŋ (12 syllables)
this department-store not sell two-door refrigerator
'This department store does not sell two-door refrigerators.'

E: 魔術師一下變出五大車茉莉花茶
mo-ʂu-ʂʐ ji-ça pʲan-ʈʂʰu wu ta ʈʂʰɤ mo-li hʷa ʈʂʰa (14 syllables)
magician at-once produce five big cart jasmine flower tea
'The magician suddenly produced five large carts of jasmine tea.'

(13) Test sentences for Shanghai ([’]= glottalization)

A: 昨日夜裡落過大雪
zo’-ɲe’ ja-li lo’ ku du ço’ (8 syllables)
yesterday night fall ASPECT big snow
'There was heavy snow last night.'

B: 依到紐約去過五十三趟
ji to ɲɤ-ÿe’ tç^{h}i ku ŋ-za’-se tã (10 syllables)
he to New-York go ASPECT five-ten-three times
'He has been to New York fifty-three times.'

C: 王醫生住在中山公園附近
Wã ji-sã z-la’ tsõ-se kõ-yü vu-tçĩ (11 syllables)
Wang doctor live-in Zhongshan park vicinity
'Dr Wang lives in the vicinity of Zhongshan Park.'

D: 這家百貨公司不賣雙門冰箱
ge’-ka pa’-hu-kõ-sz va’ ma sã-mẽ pĩ-çã (12 syllable)
this department-store not sell two-door refrigerator
'This department store does not sell two-door refrigerators.'

E: 個體戶三天買脫兩千斤奶油瓜子
ku-t^{h}i-vu se ti ma-te’ ǉã tç^{h}i tçĩ na-jɤ ko-tsz (14 syllables)
peddler 3 day sold two thousand jin cream melon-seed
'The peddler sold two thousand jin creamy melon-seeds in three days.'

Sentences A-D were syntactically and semantically identical, word for word, in the two languages. They were also identical orthographically in Chinese characters, except for six syllables (four in A and two in B, italicized in (13)) due to adaptations for dialectal vocabulary.

Sentence E was designed to see whether traditional transcription adequately reflects actual syllabic weight. In particular, except *p*^{j}*an*, all syllables in the Mandarin E appeared to be CV. Similarly, all syllables in the Shanghai E were also CV, and except *te’*, all were non-glottalized syllables. Moreover, E had the same syntactic structure and the same number of syllables in both languages. If the traditional transcription is correct, one might expect E to have similar durations in both languages. On the other hand, if the analysis in section 2 is correct, namely, a full Mandarin CV in traditional transcription is in fact a heavy syllable [CV:], with a long vowel (or a long syllabic consonant), and all syllables in Shanghai are underlyingly light CV, then the average syllable duration in E would probably be greater in Mandarin than in Shanghai.

Four Mandarin speakers and five Shanghai speakers, between the ages of 30 to 50, were used and recorded reading the test sentences. All sentences were presented in Chinese characters. Each speaker read the five sentences four times, in different random orders, for a total of 220 syllables. The speakers were given sufficient time to look at the list before recording and were instructed to read the sentences at normal speed, with no pauses within a sentence. The recordings were made in ordinary rooms. The measurements were taken using the Mac Speech Lab tools.

Average syllable durations were determined for each sentence by dividing the total duration of the sentence by the number of syllables in it. The total duration was taken by placing the initial cursor at the start of the acoustic signal (based on waveform and the spectrogram) and placing the final cursor at the end of the last strong glottal pulse. The pre-release duration of a sentence initial stop was not included in this method, but this omission should not have much effect on the average syllable duration of the whole sentence.

It might be useful if syllabic durations were measured individually, so that one may examine whether there are variations among different syllable types. In particular, it is well-known that properties like consonant voicing, vowel height and nasalization may affect duration in various ways.[14] On the other hand, one would expect that such factors should balance out over a large amount of data. Since the main goal of the present study is to find out whether, overall, Mandarin syllables are notably longer than Shanghai syllables, the present method of measurement serves the purpose.

5. Result

The measurements for Mandarin and Shanghai are respectively shown in Tables 1 and 2. As one would expect, there is some variation both for the same speaker and across speakers. As shown in (14) and Figure 1, this variation results in certain overlapping syllable durations across the two languages:

(14) Sentences with the shortest and the longest average syllable durations (in ms)

Shanghai:	shortest	123	(SH5, D, R4)
	longest	214	(SH1, A, R2)
Mandarin:	shortest	174	(M4, C, R4)
	longest	289	(M1, E, R1)

		A	B	C	D	E	**All**	SD
M1	R1	268	198	246	249	289		
	R2	253	219	227	240	248		
	R3	235	207	228	239	229		
	R4	220	186	217	216	218		
	Average	244	203	230	236	246	**232**	24
M2	R1	209	202	198	207	220		
	R2	206	195	218	205	209		
	R3	208	203	204	234	224		
	R4	210	200	213	214	231		
	Average	208	200	208	215	221	**211**	10
M3	R1	236	208	226	214	265		
	R2	214	212	217	223	231		
	R3	218	204	219	217	222		
	R4	220	198	202	210	216		
	Average	222	206	216	216	233	**218**	14
M4	R1	224	239	211	227	234		
	R2	224	191	184	203	196		
	R3	189	199	178	193	188		
	R4	194	183	174	189	178		
	Average	208	203	187	203	199	**200**	20

Table 1: Average syllable durations in Mandarin, based on four speakers (M1, M2, M3 and M4), each reading five sentences (A-E, see (12)), with four repetitions (R1-R4) for each sentence. The standard deviation (SD) for each speaker was based on the 20 tokens. Values are in ms.

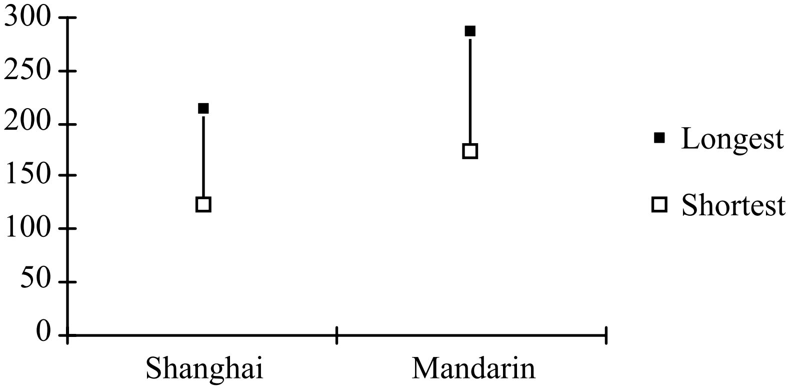


Figure 1

Range of syllable duration in Shanghai and Mandarin.

		A	B	C	D	E	**All**	SD
SH1	R1	194	185	188	181	179		
	R2	214	171	178	194	171		
	R3	174	139	168	169	187		
	R4	176	141	171	166	170		
	Average	190	159	176	178	176	**176**	17
SH2	R1	183	184	198	193	189		
	R2	166	158	174	166	176		
	R3	159	152	158	167	170		
	R4	139	143	146	142	155		
	Average	162	159	169	167	173	**166**	17
SH3	R1	156	152	158	154	166		
	R2	150	149	148	157	146		
	R3	154	149	145	145	148		
	R4	149	150	148	150	148		
	Average	152	150	150	152	152	**151**	5
SH4	R1	174	172	179	190	179		
	R2	166	171	160	189	182		
	R3	174	162	167	153	171		
	R4	173	175	163	150	166		
	Average	172	170	167	170	175	**171**	10
SH5	R1	152	160	132	129	150		
	R2	154	144	167	139	161		
	R3	139	143	158	141	157		
	R4	131	150	142	123	159		
	Average	144	149	150	133	157	**146**	12

Table 2: Average syllable durations in Shanghai, based on five speakers (SH1, SH2, SH3, SH4, and SH5), each reading five sentences (A-E, see (13)), with four repetitions (R1-R4) for each sentence. The standard deviation (SD) for each speaker was based on the 20 tokens. Values are in ms.

Our main objective, however, is to find out whether there is overall a significant difference in duration between the two languages. For this purpose, repetitions by each speaker were averaged, shown in (15), and Repeated Measure ANOVA was performed

(15) Average syllable durations in Mandarin and Shanghai (in ms)

	A	B	C	D	E
M1	244	203	230	236	246
M2	208	200	208	215	221
M3	222	206	216	216	233
M4	208	203	187	203	199
SH1	190	159	176	178	176
SH2	162	159	169	167	173
SH3	152	150	150	152	152
SH4	172	170	167	170	175
SH5	144	149	150	133	157

Repeated Measure ANOVA:

Source	p-value	Significance
Between languages	0.0005	<0.01, significant
Between sentences	0.0025	<0.01, significant
Language-sentence interaction	0.2784	>0.01, not significant

The result shows that there is a significant difference in duration between Mandarin and Shanghai. In addition, this difference is independent of the sentences used. The durational difference between Mandarin and Shanghai syllables is highlighted in (16) and Figure 2:

(16) Average syllable durations in Mandarin and Shanghai, by sentences (in ms)

	A	B	C	D	E	**All**	SD
Mandarin	221	203	210	218	225	**215**	9
Shanghai	164	157	162	160	167	**162**	4

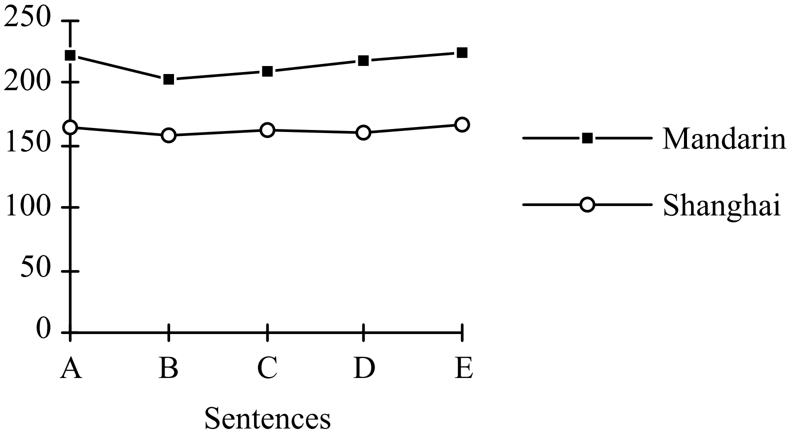


Figure 2: Average syllable durations in Mandarin and Shanghai, based on four Mandarin speakers and five Shanghai speakers, each speaking five sentences A-E four times.

The Repeated Measure ANOVA in (15) also shows a significant durational difference among the sentences A-E. It will be noted that some test sentences contain more nasal rimes (and diphthongs) than others. Since nasal rimes are traditionally transcribed as VN while simple rimes transcribed as just V, an immediate suggestion would be that the nasal codas may have increased the average syllable duration in some sentences.[15] To check this hypothesis, we compare the sentence with most nasal rimes and diphthongs with the sentence with fewest nasal rimes and diphthongs.

In Mandarin, sentence C contains most nasal rimes and diphthongs; 7 out of 11 syllables have a nasal coda, and 1 other syllable has a diphthong. In all, 8 out of 11 syllables in C, or 73%, have a coda in the traditional transcription. Sentence E has the fewest nasal rimes and codas; just 1 out of 14 syllables has a coda, or 7%. If the traditional transcription is correct, we expect C to have a longer average syllable duration than E, due to the extra duration of the coda. On the other hand, if all full Mandarin syllables are heavy, as Duanmu (1993) suggests, then what is traditionally written as [CV] must be [CV:], thus both sentences C and E should have similar average syllable durations. Consider the result below:

(17) Comparison between sentence C, in which 8/11 (73%) rimes have a coda, with E, in which just 1 out of 14 (7%) rimes has a coda, in Mandarin (in ms)

	C	E
M1	230	246
M2	208	221
M3	216	233
M4	187	199
All	**210**	**225**

Pairwise t-test:p = 0.0012 (<0.01, significant)

While there is a statistically significant durational difference between C and E, the direction of the difference is the opposite way. Instead of C having a longer average syllable duration than E, E has a longer average syllable duration than C. There is, therefore, no evidence that the nasal coda increases the duration of a full Mandarin syllable. To put it another way, there is no evidence that full syllables that are traditionally written as CV are short; they are at least just as long as a CVX syllable. This result confirms previous findings that the duration of all full Mandarin syllables are similar (Woo 1969, Howie 1976, Lin and Yan 1988), and supports the analysis that all full Mandarin syllables are heavy. The apparent difference between full V and VX rimes in traditional transcription, therefore, is misleading.

Let us now examine the effect of nasal rimes in Shanghai. We again compare C and E. In C, there are 5 nasal rimes out of 11 syllables, or 45%.[16] In E, there are just two nasal rimes out of 14 syllable (14%). Again, if nasal rimes are VN and non-nasal rimes V, as are transcribed in some works (e.g. Zhu et al 1986), then one expects C to have a considerably longer average syllable duration than E. On the other hand, if a nasal rime is just a nasalized vowel, without a coda position, then one does not expect C to be much different from E. Below is the result:

(18) Comparison between sentence C, in which 5/11 (45%) syllables have a nasal rime, with E, in which 2/14 (14%) syllables have a nasal rime, in Shanghai (in ms)

	C	E
SH1	176	176
SH2	169	173
SH3	150	152
SH4	167	175
SH5	150	157
All	**162**	**167**

Pairwise t-test:p = 0.0485

The p-value in the pairwise t-test is 0.0485, which is significant if the higher level of chance 0.05 is chosen, but not significant if the lower level of chance 0.01 is chosen. In any case, the direction of difference is once again opposite to what one expects: instead of C having a longer average syllable duration than E, E has a longer average syllable duration than C. There is, therefore, no evidence that a nasal rime increases the duration of a Shanghai syllable.

It has been noted that Shanghai has glottal rimes, which are shorter than non-glottal rimes in isolated environments (section 3). It is not clear whether glottal rimes are shorter in non-isolated environments, such as in our test sentences. To find out, we compare sentence A, which has most glottal rimes (4 out of 8 syllables, or 50%), with sentence E, which has just two glottal rimes out of 14 syllables (14%). The result is in (19):

(19) Comparison between sentence A, in which 4/8 (50%) syllables have a glottal rime, with E, in which 2/14 (14%) syllables have a glottal rime, in Shanghai (in ms)

	A	E
SH1	190	176
SH2	162	173
SH3	152	152
SH4	172	175
SH5	144	157
All	**164**	**162**

Pairwise t-test:p = 0.617 (>0.05, not significant)

The p-value shows that the difference in average syllable duration between A and E is not significant, even if the higher chance level 0.05 is chosen. There is, therefore, no evidence that glottal rimes shorten the average syllable duration in a significant way. In other words, the shorter average syllable duration in Shanghai cannot be attributed to the presence of the glottal rimes.

The same point can be seen by comparing Shanghai A, which has most glottal rimes and no nasal rimes, with Shanghai C, which has most nasal rimes and just one glottal rime. The result is shown below

(20) Comparison between sentence A, which has most glottal rimes, with C, which has most nasal rimes, in Shanghai (in ms)

	A	C
SH1	190	176
SH2	162	169
SH3	152	150
SH4	172	167
SH5	144	150
All	**164**	**162**

Pairwise t-test:p = 0.6994 (>0.05, not significant)

The p-value shows that the difference between A and E is not significant. There is, therefore, no evidence that, in non-isolated environments, glottal rimes shorten the average syllable duration or nasal rimes lengthen the average syllable duration.

6. Further discussion

We have seen that the difference between sentences A-E is significant, although there is no evidence that nasal rimes are longer or glottal rimes shorter. What, then, has lead to the fact that some sentences have longer average syllable durations than other? It will be seen in (16) that the longest average syllable duration occurs in E in both Mandarin and Shanghai. In addition, E has the most syllables in both languages. We also see that B has the shortest average syllable durations in both languages, and B has the second fewest syllables. There appears to be some correlation, then, between the syllable count of a sentence and its average syllable duration. When a sentence is long, the speaker may have broken it into several pieces and slight lengthening may have been introduced between the pieces. Since the present sample size is small, this suggestion will be left as a tentative hypothesis. In any case, as the Repeated Measure ANOVA in (15) shows, the difference among A-E is irrelevant to the durational difference between Mandarin and Shanghai.

The next point to note is that in the present study the average duration of a full Mandarin syllable was about 200 ms, but in Howie 1976 it was about 300 ms. Recall, though, that the target syllables in Howie's study were read in a carrier sentence (cf. (10)). Since the carrier sentence remained constant but the target syllables did not, the target syllables would carried extra stress, which may have led to the extra duration in Howie's study.

The final point to note is that, overall, the average syllable duration was 215 ms in Mandarin and 162 ms in Shanghai. In other words, the ratio between the average syllable duration in Mandarin and that in Shanghai was 4/3. Since full Mandarin syllables are CVX and Shanghai syllables are CV, one would ideally expect the ratio to be 3/2. One possible reason for the smaller actual ratio is that a long vowel is not always twice the length of a short vowel, so [CV:] may not always be 50% longer than [CV]. Another reason, and a more likely one, is that not all lengthening effects have been factored out in the present study. In particular, lengthening at major syntactic boundaries is likely to be present. In addition, syllable by syllable measurements of selected tokens show that the sentence final syllable is clearly longer. If non-segmental factors have contributed L to the average syllable duration in both Mandarin and Shanghai, then (3+L)/(2+L) will not be 3/2 but smaller than 3/2.

7. Implications and limitations

The present findings show that there is a significant difference in average syllable durations between Mandarin and Shanghai, independent of the presence of nasal or glottal rimes. This provides support for the phonological analysis that full Mandarin syllables are heavy, and that all Shanghai syllables are underlyingly light.

The present study also shows that full Mandarin syllables that are traditionally transcribed as CVX are not longer than those that are traditionally transcribed as CV, a result that has been found in previous phonetic studies, thus a more accurate transcription of a full CV should be [CV:].

It may seem trivial, in hindsight, that heavy syllables are longer than light syllables, a fact that is often taken for granted in a language that contrasts heavy and light syllables. However, as discussed in section 3, it is not obvious a priori whether one could make a cross-linguistic comparison of syllabic weight in terms of phonetic duration. Indeed, the phonological proposal that all full Mandarin syllables are heavy and all Shanghai syllables are light (in non-isolated environments) is not the received analysis. The present study provides phonetic evidence for the phonological proposal. In addition, it suggests that a correlation between syllabic weight and syllabic duration can exist even across languages. More generally, the present work adds support for the view that phonology and phonetics can benefit from each other, a view which many scholars have come to share.

The present study has obvious limitations. The biggest weakness is that the scale is fairly small, even though it used more speakers than some previous studies (e.g., Howie 1976, which used two speakers, and Zee and Maddieson 1979, which used one speaker). Consequently, there is a chance, however small, that the four Mandarin speakers happened to speak slowly and the five Shanghai speakers happened to speak faster, even though the speakers were picked at random. To dispel this concern, a much larger number of speakers would be needed (such as twenty speakers from each language).

Second, even if the present conclusion is valid, it still cannot be said at this point whether the same is true for M-languages and S-languages in general, due to the fact that durational studies on other tone languages are generally lacking. It is interesting, however, to note a recent study by Simpson (1993) on syllable durations in Thai. As in Mandarin, regular Thai syllables have a long vowel and/or a coda. In addition, Thai syllables generally maintain their underlying tones in context and contour tones do not split into level tones (e.g. Gandour 1974). In the present analysis, Thai is an M-language, whose full syllables should be heavy with an average duration approximating that of Mandarin. In Simpson's study, five Thai sentences, with a total of 48 syllables, were repeated four times on a written list. Four Thai speakers were each asked to read the list at normal speed. The average syllable duration in each sentence token was determined by dividing the total sentence duration by the number of syllables in it. The result was as follows.

(21) Average syllable durations in Thai, based on four speakers (Th1-Th4), each reading five sentences four times at normal speed (Simpson 1993)

Th1	Th2	Th3	Th4	Average	
222	189	225	242	**219 (ms)**	(SD = 21)

It shows that the average syllable duration in Thai is similar to that in Mandarin, as is expected in the present analysis.

A number of questions are raised but cannot be fully answered in this paper. For example, are Mandarin and Shanghai syllable-timed, or segment-timed, or stress-timed? The fact that within Mandarin or Shanghai, the average syllable duration is constant across test sentences may suggest syllable-timing. The fact that the average Mandarin syllable (CVX) is longer than the average Shanghai syllable (CV) shows some degree of segment-timing. The fact that a Shanghai syllable in an isolated domain is longer than one in a bisyllabic domain shows some degree of foot-timing or stress-timing, if stress is understood as the head of a foot (Halle and Vergnaud 1987). It seems therefore that both Mandarin and Shanghai are syllable-timed, segment-timed and stress-timed. But segment-timing can be related to syllable-timing; if a language has segment-timing and if all syllables in this language have the same number of segments, then this language will appear to have syllable-timing as well. Segment-timing must also be also related to stress-timing, since the number of segments in a syllable directly bears on syllabic weight and stress assignment. Assuming that Mandarin and Shanghai do show segment-timing (cf. Pointon 1980 for segment-timing in Spanish and Balasubramanian 1980 for segment-timing in Tamil), there is a further question, and in my view a more interesting one. Why should there be segment-timing? The present study suggests that segment-timing can be fairly consistent across-speakers and across-languages, if influences from metrical structures and syntactic boundaries can be factored out. It will be interesting, therefore, to find out whether a quantitative measure of segment-timing can be determined. Such researches will directly shed light on what the phonologist has been calling "the timing slot".

Notes

[*] I have benefited from discussions with Pam Beddor, David Evans-Romaine, Morris Halle, Michael Kenstowicz, and Shanyang Zhao during the work of the preset study. I thank my Mandarin and Shanghai speakers for providing me with free recordings. For statistical advice, I thank Ken Guire and Shanyang Zhao. Finally, I thank three anonymous reviewers and the editor of Phonology for their comments.

[1] This way of tone marking, a custom in African linguistics, is not to be confused with that of the Pinyin system (widely used by Chinese phonologists), where ˇ = fall-rise, ` = fall, and ′ = rise.

[2] Among the unitary analyses of contour tones, there are two views, illustrated below

```
(i).   a.     TBU          b.     TBU
               |                   |
             [rise]                o
                                  / \
                                  L H
```

According to (i.a), held by earlier researchers such as Pike (1948) and Wang (1967), a contour tone cannot be split at all. According to (i.b), held by more recent studies such as Chen (1986), Yip (1989), Bao (1990) and Chan (1991), a contour tone can be a cluster of level tones at one level but a unit at another. The present criticism applies to both versions of contour tone unit. More arguments against contour tone units are presented in Duanmu (1992 and to appear), including discussions on the widely cited cases of Wuxi and Danyang.

[3] Shih (1986) classifies tone languages into two types, 'syllable-tone' languages, such as Mandarin and Cantonese, where the domain of a tone pattern is the syllable, and 'word-tone' languages, such as Shanghai and African tone languages, where the domain of a tone pattern is the word. Shih further suggests that syllable-tone is found in languages with (mostly) monosyllabic words, and word-tone is found in languages with (mostly) multi-syllabic words. I am aware of no evidence, however, that Shanghai has more multi-syllabic words than Mandarin and Cantonese. In addition, the tonal domain in Shanghai is not a word, but a metrical foot, which can be larger or smaller than a word (Duanmu 1993). Finally, like other analyses, Shih overlooks a key difference between syllable-tone languages and word-tone languages, to be discussed in section 2, namely, the former have mostly heavy rimes, whereas the latter have light rimes only.

[4] By 'diphthongs' I am excluding pre-nuclear glides; for example, Mandarin [ua] 'frog' is not considered a diphthong. There are several reasons for this analysis. First, there is no phonetic evidence that the pre-nuclear glide is in the rime. As Chao (1934) points out, Mandarin [swei] 'age' is pronounced differently from [swei] 'sway' in English, in that [sw] in Mandarin is more like a single onset [s^{W}]. Second, pre-nuclear glides do not change

the syllabic weight or the tone bearing ability. Third, pre-nuclear [u] can alternate with the fricative consonant [v], so that [ua] 'frog' becomes [va]. Such evidence suggests that pre-nuclear glides are not in the rime but in the onset (cf. Duanmu 1990).

[5] An anonymous reviewer points out that Cantonese contrasts short and long vowels in closed syllables. Cheung (1986) suggests that Cantonese CVC is bimoraic and CV:C trimoraic. It will be noted, however, that in open syllables, only long vowels occur. For the present discussion, therefore, all full Cantonese syllables are heavy (whether bimoraic or trimoraic). Thus Cantonese is an M-language. Cantonese tone confirms this. When two or more full syllables occur together, each syllable retains its own tones.

[6] This is not to suggest that M-languages do not have tone sandhi. It is well-known that many M-languages, such as Mandarin, Tianjin, Fuzhou and Taiwanese, have very complicated tone sandhi. However, as pointed out in Duanmu (1993), tone sandhi in M-languages are of a very different nature, namely, a full syllable that undergoes change does not pick up a tone from another syllable; rather, what new tone it will assume must often be stipulated. For example, in Mandarin, when a syllable with the tone 213 (fall-rise) precedes another 213, the former changes to 35 (rise). However, the resulting 35 of the first syllable does not come from the second 213. Similarly, in Min dialects, the non-final syllable usually changes from its tone in isolation to a new tone, yet this new tone cannot be predicted from its neighbors but must be stipulated for each dialect. Thus, tone sandhi in M-languages is of a different nature from tone sandhi in Shanghai (and African languages), the latter basically being a re-association of tones.

As correctly pointed out by two anonymous reviewers, tone spreading can take place in M-languages. This can happen, for example, between a full syllable and a toneless syllable, especially when the full syllable carries more than two tones. In Mandarin, a toneless syllable has a higher pitch after T3 (214, or MLH) than after other tones. Duanmu (1993) suggests that the original syllable is bimoraic and can take two tones ML, and the extra tone H is then shifted to the toneless syllable. Such cases therefore support the proposed distinction between M-languages and S-languages, rather than weakening it.

[7] The determination of a tonal domain in S-languages, a domain in which tones associate and spread, is a matter of some debate. Selkirk and Shen (1990) argue that such a domain is a prosodic word. Duanmu (1993) argues that such a domain is a metrical foot. For the present discussion, the choice between the two is irrelevant. In both cases, a domain can consist of one or more syllables.

[8] It is important to note that the distinction between M-languages and S-languages is, quite naturally, a matter of degree. For example, in Shanghai, the initial syllable in a multi-syllabic domain carries just one tone. But in suburban Shanghai (or Old Shanghai), the initial syllable may carry either one or two tones (Shen 1981a, b). Duanmu (1993) suggests that Old Shanghai still has traces of an M-language, in that the stressed (initial) syllable may (optionally) remain bimoraic and carry two tones. Likewise, Suzhou, Wuxi,

and Danyang are similar to Old Shanghai in that the initial syllable may sometimes remain bimoraic and carry two tones. See Duanmu 1993 for more discussion.

[9] I am indebted to an anonymous reviewer for this point.

[10] As discussed in an earlier footnote, when a full syllable has three tones, the third will be shifted to the following toneless syllable.

[11] In segment timing, a long vowel should obviously count as two segments, so should a geminate consonant. There are two views in representing segment length. In the first, which Hayes (1989) calls the X-theory, length is represented by X-slots (or 'timing slots'). In the second, or the moraic theory, length is represented by moras. In the X-theory, therefore, segment timing means X-slot timing.

An anonymous reviewer wonders whether 'mora timing' might be a better term. I do not adopt this suggestion for two reasons. First, while the mora is certainly an important notion, it is not clear to me whether X-slots can be dispensed with entirely. Second, non-moraic segments have durations, too. For example, [tɛk] 'tech' is shorter than [tɛksts] 'texts', obviously because the latter has more segments, even though the extra segments are not moraic. Similarly, a geminate consonant is monomoraic, yet its duration is similar to that of a bimoraic vowel rather than that of a monomoraic vowel; this follows from the analysis that both a geminate consonant and a long vowel occupy two timing slots. If moras, alone, represent units of time, it is not clear how such cases are accounted for.

[12] Howie (1976) did not measure Mandarin syllable durations per se, but the duration of 'the voiced part'. However, he found that, on average, syllables with a sonorant onset are 300 ms long, while syllables with a voiceless onset are 200 ms long. If we assume that a voiceless onset has a similar duration as a sonorant onset, then all full syllables should be about 300 ms. As an anonymous reviewer points out, there is some variation across Howie's syllable tokens. But this variation did not correspond to syllable types in a systematic way, as Howie did not consider it relevant.

[13] Several remarks about the phonetic transcription are in order. First, the pre-nuclear glide is transcribed as the secondary articulation of the onset, instead of a separate segment; for phonological and phonetic arguments, see footnote 4 and Duanmu 1993. Second, it will be noted that some syllables have a syllabic consonant, such as [ʂʐ] in Mandarin B, which in other transcriptions are sometimes transcribed with a so-called "apical vowel". Third, some Shanghai syllables appear to consist of a single consonant, such as [ŋ] in S3 and [z] in S4. Strictly speaking, this consonant occupies both the onset position and the nuclear position, since all Shanghai syllables are CV (Duanmu 1993). Fourth, it was argued in section 2 that all Mandarin full syllables are CVX (where V could be a syllabic consonant and X could be a coda or additional length), thus a CV syllable should strictly speaking be [CV:]. Since this is something to be confirmed in the

present experiment, length is not marked in advance. Finally, for simplicity, tones are not transcribed, primarily because there is extensive tone sandhi in Shanghai. Transcribing the underlying tones alone could be misleading, while transcribing both the underlying and the surface tones could be distractive.

[14] An anonymous reviewer correctly points out that tone may affect syllable duration as well. All studies agree that of the four Mandarin tones, T2 (rise) and T3 (fall-rise or low-rise) are longer than T1 (high level) and T4 (fall). For example, according to Luo and Wang (1957: 127), T2 is 7% longer than T4, and according to Howie (1976: 220), T2 is 3% longer than T4. In non-final positions, T3 is 10% longer than T4 (Howie 1976: 20). The difference between Mandarin T1 and T4, however, is not obvious; Luo and Wang report that T1 is 2.6% longer than T4, while Howie reports that T4 is 6% longer than T1.

In designing the Mandarin sentences, no attempt was made to control the proportions of tone types. What effect would it have if different proportions of tone types were used? Consider the current proportions, given below

(i)	T1	T2	T3	T4	Total	
	19	9	6	21	55	(number of syllables)

Out of the 55 syllables used, 44 (73%) were T1 and T4, the shortest two tones in Mandarin. If more T2 and T3 were used, as a more balanced selection probably would require, and if the durational differences between different tones exist not just in isolated environments but also in connected speech, then the average syllable duration in Mandarin would be increased. In other words, the result that the average syllable duration is longer in Mandarin than in Shanghai, to be discussed in section 5, cannot be not due to an unduly high proportion of T2 and T3. In addition, the size of the difference in average syllable duration between Mandarin and Shanghai (at a ratio of 4:3) considerably exceeds the size of the difference between Mandarin T2 and T3 on the one hand and T1 and T4 on the other.

In Shanghai, when all monosyllabic domains are avoided, all syllables will be either H or L at surface. If all domains are bisyllabic, as the test sentences attempted to achieve, there would be about an equal number of surface H's and L's. I am, however, not aware of intrinsic durational differences between H and L.

[15] This issue was raised by an anonymous reviewer.

[16] Due to sound change, some cognate rimes are nasal in Mandarin but non-nasal in Shanghai.

REFERENCES

Abercrombie, David. 1964. Syllable quantity and enclitics in English. In *In Honor of Daniel Jones*, ed. David Abercrombie, Dennis B. Fry, P.A.D MacCarthy, N.C. Scott and John L.M. Trim, 216-222. London: Longman.

Ao, Benjamin X.P. 1993. Phonetics and phonology of Nantong Chinese. Doctoral dissertation, Ohio State University, Columbus.

Balasubramanian, T. 1980. Timing in Tamil. *Journal of Phonetics* 8.4: 449-468.

Bao, Zhiming. 1990. On the nature of tone. Doctoral dissertation, MIT, Cambridge, Mass.

Bao, Zhiming. 1992. Toward a typology of tone sandhi. paper presented at BLS 28 Special Session on the Typology of Tonal Systems, February 14, Berkeley.

Beckman, Mary, and Jan Edwards. 1990. Lengthening and shortening and the nature of prosodic constituency. In *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech*, ed. John Kingston and Mary Beckman, 152-178. Cambridge, England: Cambridge University Press.

Catford, J.C. 1977. *Fundamental Problems in Phonetics*. Bloomington: Indiana University Press.

Chan, Marjorie K.M. 1991. Contour-tone spreading and tone sandhi in Danyang Chinese. *Phonology* 8.2: 237-259.

Chao, Yuen-Ren. 1928. *Xiandai Wuyu Yanju* [Studies in the Modern Wu dialects], Peking: Tsing Hua University Press.

Chao, Yuen-Ren. 1934. The non-uniqueness of phonemic solutions of phonetic systems. *Bulletin of Institute of History and Philology*, Academia Sinica 4.4: 363-397. Reprinted in *Readings in Linguistics I*, ed. Martin Joos, 1957: 38-54. Chicago: University of Chicago Press.

Chao, Yuen-Ren. 1967. Contrastive aspects of the Wu dialects. *Language* 43.1: 92-101.

Chen, Matthew. 1986. An overview of tone sandhi phenomena across Chinese dialects. Paper presented at the Conference on Languages and Dialects of China, Berkeley, California.

Chen, Matthew. 1992. Tone rule typology. Paper presented at BLS 28 Special Session on the Typology of Tonal Systems, Berkeley, February 1992.

Cheung, Kwan-Hin. 1986. The phonology of present-day Cantonese. Doctoral dissertation, University of London, England.

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

Duanmu, San. 1992. Re-examining contour tone units in Chinese languages. Paper presented at BLS 18 Special Session on the Typology of Tonal Systems, February 14, Berkeley.

Duanmu, San. 1993. Rime length, stress, and association domains. *Journal of East Asian Linguistics* 2.1: 1-44.

Duanmu, San. To appear. Against contour tone units. *Linguistic Inquiry*.

Gandour, Jack T. 1974. On the representation of tone in Siamese. *UCLA Working Papers in Phonetics* 427: 118-146.

Gandour, Jack, and Victoria Fromkin. 1978. On the phonological representation of contour tones. *Linguistics of the Tibeto-Burman Area* 4.1: 73-74.

Goldsmith, John. 1976. *Autosegmental phonology*. Bloomington: Indiana University Linguistics Club.

Halle, Morris, and Jean-Roger Vergnaud. 1987. *A Essay on Stress*. Cambridge, Mass.: MIT Press.

Hayes, Bruce. 1989. Compensatory lengthening in moraic phonology. *Linguistic Inquiry* 20.2: 253-306.

Howie, John. 1976. *An Acoustic Study of Mandarin Tones and Vowels*. London: Cambridge University Press.

Jin, Shunde. 1986. Shanghai morphotonemics: A preliminary study of tone sandhi behavior across word boundaries. Bloomington: Indiana University Linguistics Club.

Kao, Diana. 1971. *Structure of the Syllable in Cantonese*. The Hague: Mouton.

Klatt, Dennis H. 1975. Vowel lengthening is syntactically determined in a connected discourse. *Journal of Phonetics* 3.3: 129-140.

Ladefoged, Peter. 1982. *A Course in Phonetics*. 2nd edition. San Diego: Harcourt Brace Jovanovic.

Leben, William. 1973. Suprasegmental phonology. Doctoral dissertation, MIT, Cambridge, Mass.

Lehist, Ilse. 1973. Phonetic disambiguation of syntactic ambiguity. *Glossa* 7.2: 107-121.

Lehist, Ilse. 1977. Isochrony reconsidered. *Journal of Phonetics* 5: 253-263.

Lin, Maochan, and Jingzhu Yan. 1988. The characteristic features of the final reduction in the neutral-tone syllable of Beijing Mandarin. *Phonetic Laboratory Annual Report of Phonetic Research*, Phonetic Laboratory, Institute of Linguistics, Chinese Academy of Social Sciences, Beijing, 37-51.

Luo, Chang-Pei, and Jun Wang. 1957. *Putong Yuyinxue Gangyao* [Outline of General Phonetics]. Peking: Kexue Chubanshe. Reprinted in 1981 by Shangwu Yinshuguan.

Lü, Shuxiang. 1947. Danyang hua li de lianci bian tone [Tone sandhi in the Tan-yang dialect]. *Bulletin of Chinese Studies* vol. 7, 225-238.

Lü, Shuxiang. 1980. Danyang fangyan de shengdiao xitong [The tonal system of the Danyang dialect]. *Fangyan* 1980.2, 85-122.

McCarthy, John, and Alan Prince. 1990. Foot and word in prosodic morphology: The Arabic broken plural. *Natural Language and Linguistic Theory* 8.2, 209-284.

Pike, Kenneth. 1945. *The Intonation of American English*. Ann Arbor: University of Michigan Press.

Pike, Kenneth. 1948. *Tone Languages*. Ann Arber: University of Michigan Press.

Pointon, Graham E. 1980. Is Spanish really syllable-timed? *Journal of Phonetics* 8.3: 293-304.

Prince, Alan. 1992. Quantitative consequences of rhythmic organization. In *Papers from the 26th Regional Meeting of the Chicago Linguistic Society Volume 2: The Parasession on the Syllable in Phonetics and Phonology*, 355-398. Chicago Linguistic Society, University of Chicago, Chicago, Ill.

Pulleyblank, Douglas. 1986. *Tone in Lexical Phonology*. Dordrecht: Reidel.

Qian, Nairong, and Rujie Shi. 1983. Remarks on the tone sandhi of Suzhou. *Fangyan* 83.4, 275-296.

Selkirk, Elizabeth, and Tong Shen. 1990. Prosodic domains in Shanghai Chinese. In *The Phonology-Syntax Connection*, ed. Sharon Inkelas and Draga Zec, 313-337. CSLI monograph, University of Chicago Press, Chicago.

Shen, Tong. 1981a. Lao pai Shanghai fang yan de lian du bian diao [Tone sandhi in Old Shanghai]. *Fangyan* 1981.2, 131-144.

Shen, Tong. 1981b. Shanghai hua laopai xinpai de chabie [Differences between Old and New Shanghai dialects]. *Fangyan* 1981.4, 275-283.

Shen, Tong. 1982. Lao pai Shanghai fang yan de lian du bian diao [2] [Tone sandhi in Old Shanghai, Part 2]. *Fangyan* 1982.2, 100-114.

Sherard, Michael. 1972. Shanghai phonology. Doctoral dissertation, Cornell University, Ithaca, N.Y.

Shih, Chi-lin. 1986. The prosodic domain of tone sandhi in Chinese. Doctoral dissertation, University of California, San Diego.

Simpson, Rita. 1993. Syllable length in Thai. Ms., University of Michigan, Ann Arbor.

Wang, Futang. 1959. Shaoxing hua ji yin [A description of Shaoxing sounds]. *Yuyanxue Luncong* 3: 73-126.

Wang, Hongjun. 1991. Tonal system of Shaoxing dialect. Ms., MIT, Cambridge, Mass.

Wang, William S-Y. 1967. Phonological features of tone. *IJAL* 33.2: 93-105.

Whalen, Dough H., and Patrice S. Beddor. 1989. Connections between nasality and vowel duration and height: Elucidation of the Eastern Algonquian intrusive nasal. *Language* 65.3: 457-486.

Williams, Edwin. 1976. Underlying tone in Margi and Igbo. *Linguistic Inquiry* 7.3: 436-468.

Woo, Nancy. 1969. Prosody and phonology. Doctoral dissertation, MIT, Cambridge, Mass.

Xie, Zili. 1982. Suzhou fangyan liang zi zu de lian du biandiao [Tone sandhi in bisyllabic phrases in Suzhou]. *Fangyan* 82.4: 245-263.

Xu, Baohua, Zhenzhu Tang, Rujie You, Nairong Qian, Rujie Shi, and Yaming Shen. 1988. *Shanghai Shiqü Fangyan Zhi* [Urban Shanghai Dialects]. Shanghai: Shanghai Jiaoyu Chubanshe.

Ye, Xiang-ling. 1979. Suzhou fangyan de lian du biandiao [Tone sandhi in Suzhou]. *Fangyan* 79.1: 30-46.

Yip, Moira. 1980. Tonal phonology of Chinese. Doctoral dissertation, MIT, Cambridge, Mass.

Yip, Moira. 1989. Contour tones. *Phonology* 6: 149-174.

Yip, Moira. 1992. The spreading of tonal nodes and tonal features in Chinese dialects. Paper presented at BLS 28 Special Session on the Typology of Tonal Systems, Berkeley, February 1992.

Zee, Eric, and Ian Maddieson. 1979. Tones and tone sandhi in Shanghai: Phonetic evidence and phonological analysis. *UCLA Working Papers in Phonetics*, March, 93-129.

Zhu, Chuan, Jia-ji Min, Song-yue Zhang, and Xiao Fan. 1986. *Jianming Wu Fangyan Cidian* [A Concise Dictionary of Wu Dialects], Shanghai: Shanghai Ci Shu Chubanshe.