pISSN 2005-8063
eISSN 2586-5854
2018. 12. 31.
Vol.10 No.4
pp. 39-44

말소리와 음성과학
Phonetics and Speech Sciences

한국음성학회지
https://doi.org/10.13064/KSSS.2018.10.4.039

A study of the preconsonantal vowel shortening in Chinese*

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Abstract

This study aimed to examine whether preconsonantal vowel shortening, which occurs in many languages, exists in Chinese. To this end, we compared 15 pairs of Chinese bi-syllabic words with intervocalic unaspirated/aspirated stops. The results revealed that (1) the effect of the feature aspiration of the following stop on the preceding vowel (V1) was neither significant nor consistent though V1 tends to be a little longer before an unaspirated stop; (2) the following unaspirated stop closure (C) was similar to or longer than its aspirated cognate; (3) the durational sum of V1 and C was longer when the stop is unaspirated, and V1 and C had no compensatory relationship; (4) Voice Onset Time (VOT) was significantly longer when the stop is aspirated than unaspirated; (5) the vowel (V2) following VOT was significantly longer when the stop is unaspirated, so the differentials in VOT were partially compensated; (6) despite the partial compensation, the sum of VOT and V2 was longer when the stop is aspirated; (7) words with an intervocalic aspirated stop were longer than those with its unaspirated cognate. It is concluded that while VOT is the most important factor for deciding the timing structure of Chinese words with intervocalic stops, closure duration is crucial for Korean and many other languages.

Keywords: Chinese stops, preconsonantal vowel shortening, vowel, closure duration, VOT (aspiration)

1. Introduction

One of the phonetic and phonological phenomena observed in many languages is the preconsonantal vowel (syllable) shortening (e.g., English: House & Fairbanks, 1953; Peterson & Lehiste, 1960; French: Chen, 1970; Mack, 1982; Spanish: Delattre, 1962; Zimmerman & Sapon, 1958; Norwegian: Fintoft, 1961; Dutch: Slis & Cohen, 1969; Van den Berg, 1988; Japanese: Port, *et al*., 1987; Sato, 1993; Tamil: Balasubramanian, 1981; Hindi: Maddieson & Gandour, 1975; Russian: Chen, 1970; German: Kohler, 1979; Swedish: Carlson & Granström, 1986; Elert, 1964; Arabic: Alghamdi, 1990; Korean: Chen, 1970; Kim, 1965; Kim, 1987; Oh, 2002; Oh & Johnson, 1997; Yun, 2004, 2009, 2010). That is, a vowel or syllable in many languages is shorter before phonologically voiceless or tense obstruents within a syllable and/or across the syllable boundary while it is longer before their voiced or lax cognates.

On the other hand, it is surprising that few studies of Chinese have been reported with regard to the preconsonantal vowel (syllable) shortening, though Chinese is a language that is currently

* This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2015S1A5B5A07042773).
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Received 30 October 2018; Revised 26 November 2018; Accepted 30 November 2018

used by more than 1.4 billion people even in mainland China only. The shortening has been observed in languages whose stops are distinguished by the feature ±voice or ±tense. Interestingly, Chinese stops are not distinguished by voicing or tenseness. They are all phonologically voiceless as Korean stops are. However, unlike Korean stops with three-way distinctions by aspiration and tenseness (Kim, 1965), they are distinguished only by the feature aspiration (Lin, 2007). Now, it is worthwhile to examine whether the preceding vowel duration varies as a function of the feature aspiration of the following stop in Chinese.

Though the preconsonantal vowel (syllable) shortening is found in many languages, the degree or pattern of the durational variation differs between languages. First, it has been known that out of many languages, English reveals the greatest variation of vowel duration as a function of the following consonant, i.e., the vowel before a voiceless consonant is much shorter than that before its voiced counterpart (Chen, 1970; Zimmerman & Sapon, 1958). For instance, Chen (1970) calculated the average ratios of vowel duration before voiceless vs. voiced consonants in seven languages. The results showed that English had the lowest ratio: 0.61 in English, 0.87 in French, 0.82 in Russian, 0.78 in Korean, 0.90 in German, 0.86 in Spanish and 0.82 in Norwegian. However, especially the comparison between English and Korean was not fair because most of the test words in English were mono-syllabic whereas all the words were bi-syllabic in Korean. With regard to this, it should be noted that Korean stops become neutralized at coda position, i.e., no phonetic distinction between tense/lax stops (Martin, 1951). Unlike within a syllable, Korean is more remarkable than English in the variation of the preceding vowel duration across a syllable boundary (Kim, 1987; Yun, 2004, 2009, 2010).

Second, the following consonant closure duration also varies from language to language. For example, Chen (1970) reported that while the average durational ratio between English voiced consonant closures and their voiceless cognates was 1 : 1.59, it was 1 : 2.3 between Korean ones - Chen (1970) classified Korean consonants (stops and affricates) into two groups (voiced vs. voiceless) as in English. Kim (1987) observed that for English the ratio was 1 : 1.22, whereas for Korean the ratio between the three types (phonologically voiceless lax unaspirated stops /p, t, k/, voiceless tense unaspirated stops /p', t', k'/, and voiceless tense aspirated stops /p^h, t^h, k^h/) of stop closure durations was 1 : 3.36 : 2.52. Yun (2009) also reported that the average ratio between the three types of Korean stop closure durations was 1 (lax unaspirated) : 2.55 (unaspirated tense) : 2.14 (aspirated tense). The three studies suggest that the mean ratio between closure durations of tense vs. lax or voiceless vs. voiced consonants (stops and affricates) is much greater in Korean than in English.

Third, in English and Japanese, the preceding vowel (V) and the following stop closure (C) fully compensate for each other in duration (Port, 1981; Port, *et al*., 1987). That is, the micro-units (V, C) show inverse temporal variations, whereas the macro-unit (V+C) remains unchanged irrespective of the feature ±voice of the following consonant C. In Korean, however, the sum of vowel and consonant durations differs depending on the feature ±tense of the following consonant, i.e., V + tense C is longer than V + lax C. This means that the macro-unit V+C of Korean shows a pattern different from those of English and Japanese. The cross-linguistically different timing patterns between V and C are demonstrated in Yun (2010) where Korean, English, Japanese, and Arabic data are compared (see Figure 1). The compared data include Korean words (papa vs. pap'a vs. pap^ha), English words (dibber vs. dipper and deeber vs. deeper) from Port (1981), Japanese words (kada vs. kata) from Port, *et al*. (1987), and Arabic words (badar vs. batar) from Alghamdi (1990). In Korean, solid lines with white circles indicate V and dotted lines VOT+V. Solid lines with white circles indicate V in Arabic, but VOT+V in English and Japanese. Figure 1 clearly shows that Korean V and C partly compensate for each other whereas the V and C reveal full compensations in the other three languages.

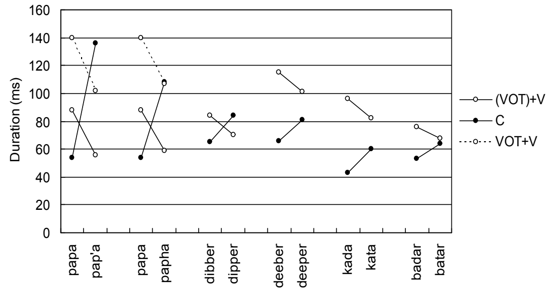

Figure 1. Comparison of durational variations between the preceding vowel (V) and the following stop closure (C) in Korean, English, Japanese and Arabic (Yun, 2010, p. 86, Figure 2)

Not only V+C but also words with an intervocalic stop in Korean are significantly longer when the stop is tense than when it is lax. For example, Sato (1993) reported that /mamp'i/ and /$mamp^h$i/, which were similar in duration, were longer than /mampi/. Yun (2004) also showed that /ap'a/ and /ap^ha/, which were similar in duration, were longer than /apa/. It is because the durational differentials in V+C remain at word level in Korean (Yun, 2004).

As mentioned so far, many languages show the preconsonantal vowel (syllable) shortening, but the degree or pattern of temporal variation differs between languages. Chinese also must have its own typical timing pattern between V and C. In order to discover the pattern, this study examined both the temporal micro-units (V, C, VOT) and macro-units (V+C, word) of Chinese.

2. Method

2.1. Informants

Five (one male and four female) native speakers of Mandarin took part in the recording. They were all undergraduate students of Hankuk University of Foreign Studies at their twenties.

2.2. Stimuli

As seen in Table 1, 15 pairs of bi-syllabic Chinese words were chosen as stimuli. All the words (five pairs with bilabial stops /p, p^h/; five pairs with alveolar stops /t, t^h/; five pairs with velar stops /k, k^h/) have one of Chinese unaspirated/aspirated stops (/p, p^h, t, t^h, k, k^h/) at the onset of the second syllable. The target words were embedded in a carrier sentence, 请把 _____ 再说一遍 [qiŋ pa _____ zài shuō yībiàn] ‘Please say _____ again.’ As a result, we obtained 30 sentences. Reading lists were prepared in which those sentences were written in ten different orders. The five informants were asked to read the lists at their normal rate to produce 1,500 tokens (5 informants × 30 words × 10 lists). Their speech was directly recorded into a computer through a microphone in the sound treated recording room of the Speech Laboratory at Hankuk University of Foreign Studies. The recording was digitised at a sampling rate of 16 kHz with 16 bit resolution and saved as files to be processed by the software package Praat.

Table 1. Stimuli

/p/	/pʰ/
老伯 /lǎopó/ father's elder brother	老婆 /lǎopʰó/ a wife
胳膊 /gēpó/ an arm	割破 /gēpʰò/ to get cut
隔壁 /gépì/ a neighbor's house	革皮 /gépʰí/ leather
七遍 /qīpiàn/ number 7	欺骗 /qīpʰiàn/ to cheat
改变 /gǎipiàn/ to change	钙片 /gàipʰiàn/ a calcium pill
/t/	/tʰ/
浦东 /pǔtōŋ/ a city name	普通 /pǔtʰōŋ/ commonness
祈祷 /qítǎo/ to pray	乞讨 /qítʰǎo/ to beg for money
缅甸 /miǎntiàn/ Myanmar	腼腆 /miǎntʰiǎn/ to be shy
省道 /shěŋtào/ a thoroughfare	绳套 /shéŋtʰào/ a trap
替代 /tìtài/ to replace	体态 /tǐtʰài/ a body shape
/k/	/kʰ/
投稿 /tóukǎo/ a contribution	投靠 /tóukʰào/ to entrust to care
国歌 /guókē/ a nation	过客 /guòkʰè/ a passer-by
诗歌 /shīkē/ a poem	食客 /shíkʰè/ a hanger-on
几个 /jǐkè/ some	饥渴 /jīkʰě/ hunger and thirst
骨骼 /kǔké/ a framework	顾客 /kùkʰè/ a customer

2.3. Measurement and statistics

First, we measured the 1st syllable duration - when the onset is a lateral /l/: /l/ + preceding vowel duration (V1); when the onset is a stop: closure duration (C1) + VOT1 + preceding vowel duration (V1); when the onset is an affricate (e.g., /qī/, /jī/): C1 + affrication (for convenience it is counted as VOT1) + V1; when the onset is a fricative (e.g, /shéŋ/, /shí/): frication + V1 (for convenience the coda /ŋ/ was counted as part of V1); when the onset is a nasal (e.g., /miǎn/): nasal duration + V1 (for convenience the final /n/ was counted as part of V1). Second, we measured the 2nd syllable duration - closure duration (C2) of the intervocalic stops + aspiration (VOT2) + vowel (V2) (for convenience the codas /ŋ, n/ were counted as part of V2). Finally, the whole word duration was measured.

We obtained averages (ms), SD and SE, with performing repeated measures ANOVAs.

3. Results and Discussion

3.1. Preceding vowel: V1

As seen in Table 2, the preceding vowel (V1) is generally longer when the intervocalic consonant is unaspirated than when it is aspirated. But statistically significant differences were observed from only two out of the 15 pairs, and even the differences were not great (p = 0.032, 0.039). Furthermore, some vowels were longer before aspirated stops (e.g., /gǎipiàn/ 147 ms *vs*. /gàipʰiàn/ 156 ms). Therefore, it can be said that overall, the effect of the feature aspiration on V1 was neither significant nor consistent though V1 is liable to be a little longer before an unaspirated stop. This means that there is no significant preconsonantal vowel shortening in Chinese.

Table 2. V1: Averages (ms), F ratios, p-values

Word	N.Asp	Asp	$F(1, 4)$	p-value
/lǎopó/ vs. /lǎopʰó/	157	149	10.441	0.032*
/gēpó/ vs. /gēpʰò/	151	145	1.751	0.256 ns
/gépì/ vs. /gépʰí/	146	139	1.551	0.281 ns
/qīpiàn/ vs. /qīpʰiàn/	91	79	9.131	0.039*
/gǎipiàn/ vs. /gàipʰiàn/	147	156	4.058	0.114 ns
/pǔtōŋ/ vs. /pǔtʰōŋ/	94	88	2.025	0.228 ns
/qítǎo/ vs. /qítʰǎo/	84	83	0.109	0.758 ns
/miǎntiàn/ vs. /miǎntʰiǎn/	187	186	0.012	0.918 ns
/shěŋtào/ vs. /shéŋtʰào/	156	156	0.002	0.97 ns
/tìtài/ vs. /tǐtʰài/	95	79	3.143	0.151 ns
/tóukǎo/ vs. /tóukʰào/	139	126	7.1	0.056 ns
/guókē/ vs. /guòkʰè/	156	144	3.553	0.133 ns
/shīkē/ vs. /shíkʰè/	97	94	0.545	0.501 ns
/jǐkè/ vs. /jīkʰě/	101	113	2.389	0.197 ns
/kǔké/ vs. /kùkʰè/	133	123	4.14	0.112 ns

* p<0.05; ** p<0.01; *** p<0.001; ns: not significant

3.2. (VOT1)+V1

Repeated measures ANOVAs on [(VOT1)+V1] were performed in accordance with Port, *et al*. (1987) which regards VOT as part of the following vowel. The results were similar to those of V1 (see Table 3). That is, VOT1 (or affrication)+V1 was generally longer before unaspirated stops than aspirated ones. However, except for three pairs, the differences were not significant. In addition, two pairs showed the opposite results, i.e., /gǎipiàn/ (163 ms) vs. /gàipʰiàn/ (172 ms); /jǐkè/ (165 ms) vs. /jīkʰě/ (174 ms), and one pair had the same length, i.e., /shěŋtào/ (156 ms) vs. /shéŋtʰào/ (156 ms). To summarize, a vowel tends to be a little longer before unaspirated stops, but the trend is weak and inconsistent. It again indicates that Chinese has no significant preconsonantal vowel shortening. This is very different from English and Korean in which the distinctive feature voicing or tenseness of the following consonant causes significant durational differences in the preceding vowel.

Table 3. (VOT1)+V1: Averages (ms), F ratios, p-values

Word	N.Asp	Asp	F (1, 4)	p-value
/lǎopó/ vs. /lǎopʰó/	157	149	10.441	0.032*
/gēpó/ vs. /gēpʰò/	182	175	2.289	0.205 ns
/gépì/ vs. /gépʰí/	179	170	1.53	0.284 ns
/qīpiàn/ vs. /qīpʰiàn/	220	201	13.399	0.022*
/gǎipiàn/ vs. /gàipʰiàn/	163	172	3.73	0.126 ns
/pǔtōŋ/ vs. /pǔtʰōŋ/	171	162	5.964	0.071 ns
/qítǎo/ vs. /qítʰǎo/	206	199	17.261	0.014*
/miǎntiàn/ vs. /miǎntʰiǎn/	187	186	0.012	0.918 ns
/shěŋtào/ vs. /shéŋtʰào/	156	156	0.002	0.97 ns
/tìtài/ vs. /tǐtʰài/	186	173	2.759	0.172 ns
/tóukǎo/ vs. /tóukʰào/	209	199	2.535	0.187 ns
/guókē/ vs. /guòkʰè/	186	173	4.41	0.104 ns
/shīkē/ vs. /shíkʰè/	97	94	0.545	0.501 ns
/jǐkè/ vs. /jīkʰě/	165	174	2.036	0.227 ns
/kǔké/ vs. /kùkʰè/	162	154	7.324	0.054 ns

* p<0.05; ** p<0.01; *** p<0.001; ns: not significant

3.3. Intervocalic consonant: closure duration (C2)

Closure duration (C2) of unaspirated intervocalic stops was significantly longer than that of aspirated ones in six out of the 15 pairs (see Table 4). However, the trend was not consistent. In the other nine pairs, C2 did not statistically differ depending on the feature aspiration of the intervocalic stops. C2 was even shorter in unaspirated stops than in aspirated ones in three pairs (/gēpó/ (41 ms) vs. /gēp^{h}ò/ (45 ms); /tìtài/ (37 ms) vs. /tǐt^{h}ài/ (41 ms); /tóukǎo/ (30 ms) vs. /tóuk^{h}ào/) (32 ms)), or the same in one pair (/lǎopó/ (60 ms) vs. /lǎop^{h}ó/ (60 ms)). All in all, however, we can say that the closure duration of Chinese unaspirated stops is similar to or longer than that of aspirated ones.

Table 4. C2: Averages (ms), *F* ratios, *p*-values

Word	N.Asp	Asp	*F*(1, 4)	*p*-value
/lǎopó/ vs. /lǎop^{h}ó/	60	60	0.000	0.984 ns
/gēpó/ vs. /gēp^{h}ò/	41	45	2.638	0.18 ns
/gépì/ vs. /gép^{h}í/	46	40	5.558	0.078 ns
/qīpiàn/ vs. /qīp^{h}iàn/	45	37	5.247	0.084 ns
/gǎipiàn/ vs. /gàip^{h}iàn/	60	38	16.64	0.015*
/pǔtōŋ/ vs. /pǔt^{h}ōŋ/	42	31	89.542	0.001**
/qítǎo/ vs. /qít^{h}ǎo/	36	28	12.512	0.024*
/miǎntiàn/ vs. /miǎnt^{h}iǎn/	35	21	18.27	0.013*
/shěŋtào/ vs. /shéŋt^{h}ào/	32	22	15.861	0.016*
/tìtài/ vs. /tǐt^{h}ài/	37	41	2.204	0.212 ns
/tóukǎo/ vs. /tóuk^{h}ào/	30	32	0.5	0.518 ns
/guókē/ vs. /guòk^{h}è/	41	36	7.115	0.056 ns
/shīkē/ vs. /shík^{h}è/	41	38	1.064	0.361 ns
/jīkè/ vs. /jīk^{h}ě/	51	39	3.882	0.12 ns
/kǔké/ vs. /kùk^{h}è/	44	31	12.657	0.024*

* *p*<0.05; ** *p*<0.01; *** *p*<0.001; ns: not significant

3.4. (VOT1)+V1+C2

As seen in Table 5, when the intervocalic stop (C2) is unaspirated, (VOT1)+V1+C2 was longer in seven of the 15 pairs, and it was almost significantly longer in three other pairs (/gépì/ vs. /gép^{h}í/, *p*=0.061; /gǎipiàn/ vs. /gǎip^{h}iàn/, *p*=0.061; /jīkè/ vs. /jīk^{h}è/, *p*=0.055). In the other five pairs, (VOT1)+V1+C2 was a little longer when the stop is unaspirated, though the differences were not significant (*p*>0.1). In conclusion, the durational unit of (VOT1)+V1+C2 in Chinese tends to be longer when the stop is unaspirated than aspirated.

Table 5. (VOT1)+V1+C2: Averages (ms), *F* ratios, *p*-values

Word	N.Asp	Asp	*F*(1, 4)	*p*-value
/lǎopó/ vs. /lǎop^{h}ó/	216	208	1.496	0.288 ns
/gēpó/ vs. /gēp^{h}ò/	223	220	0.51	0.515 ns
/gépì/ vs. /gép^{h}í/	225	210	6.722	0.061 ns
/qīpiàn/ vs. /qīp^{h}iàn/	264	238	16.74	0.015*
/gǎipiàn/ vs. /gàip^{h}iàn/	223	209	6.685	0.061 ns
/pǔtōŋ/ vs. /pǔt^{h}ōŋ/	213	194	21.424	0.01*
/qítǎo/ vs. /qít^{h}ǎo/	242	226	100.829	0.001**
/miǎntiàn/ vs. /miǎnt^{h}iǎn/	222	207	11.768	0.027*
/shěŋtào/ vs. /shéŋt^{h}ào/	189	178	47.045	0.002**
/tìtài/ vs. /tǐt^{h}ài/	223	214	1.815	0.249 ns
/tóukǎo/ vs. /tóuk^{h}ào/	239	231	2.826	0.168 ns
/guókē/ vs. /guòk^{h}è/	227	209	8.755	0.042*
/shīkē/ vs. /shík^{h}è/	138	132	1.137	0.346 ns
/jīkè/ vs. /jīk^{h}ě/	216	213	7.25	0.055 ns
/kǔké/ vs. /kùk^{h}è/	206	185	27.904	0.006**

* *p*<0.05; ** *p*<0.01; *** *p*<0.001, ns: not significant

As said earlier, many languages have a compensatory temporal movement between the preceding vowel and the following consonant, whether the compensation is full or partial. However, such a compensation did hardly occur in Chinese, considering the durational variations of (VOT1)+V1 and C2 that were introduced in the previous sections. That is, regardless of statistical significance, each of the preceding vowel (VOT1)+V1 and the following consonant (C2) was generally longer when the stop is unaspirated than aspirated. Therefore, the sum of (VOT1)+V1 and C2 also was longer when the stop is unaspirated. A relatively longer preceding vowel and a relatively longer following unaspirated stop made a longer duration than the duration a relatively shorter vowel and a relatively shorter aspirated stop did. Compensation between V and C takes place with a long vowel and a short consonant or with a short vowel and a long consonant. However, it did not occur in Chinese.

One pair (/kǔké/ vs. /kùk^{h}è/) out of the test words is demonstrated in Figure 2. No noticeable durational compensation is seen between V and C in Figure 2, while clear compensations are seen in the four languages in Figure 1.

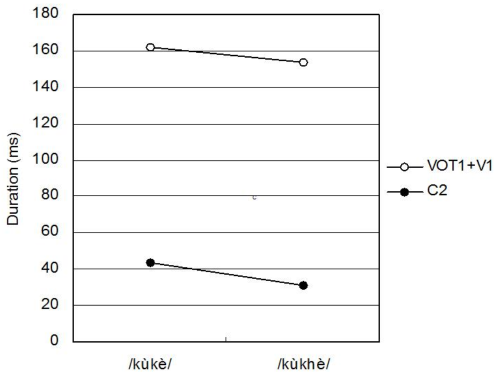

Figure 2. A comparison of durational variations between the preceding vowel (VOT1+V1) and the following stop closure (C2) in Chinese

3.5. VOT2

As expected, all of the 15 word pairs were significantly distinguished by VOT2 (see Table 6). This proves that aspiration is the distinctive feature of Chinese stops. Velar consonants /k, k^h/ had relatively longer VOTs than bilabial and alveolar stops as in other languages, e.g., Korean. In particular, unaspirated /k/ revealed notably longer VOTs than /p, t/.

Table 6. VOT2: Average (ms), *F* ratios, *p*-values

Word	N.Asp	Asp	*F*(1, 4)	*p*-value
/lǎopó/ vs. /lǎop^{h}ó/	16	72	170.585	0.000***
/gēpó/ vs. /gēp^{h}ò/	9	64	178.84	0.000***
/gépì/ vs. /gép^{h}í/	13	87	39.983	0.003**
/qīpiàn/ vs. /qīp^{h}iàn/	9	72	135.903	0.000***
/gǎipiàn/ vs. /gàip^{h}iàn/	7	70	144.501	0.000***
/pǔtōŋ/ vs. /pǔt^{h}ōŋ/	11	66	106.699	0.000***
/qítǎo/ vs. /qít^{h}ǎo/	11	69	43.268	0.003**
/miǎntiàn/ vs. /miǎnt^{h}iǎn/	17	69	502.84	0.000***
/shěŋtào/ vs. /shéŋt^{h}ào/	11	74	67.38	0.001**
/tìtài/ vs. /tǐt^{h}ài/	11	72	36.75	0.004**
/tóukǎo/ vs. /tóuk^{h}ào/	22	79	55.11	0.002**
/guókē/ vs. /guòk^{h}è/	34	83	76.128	0.001**
/shīkē/ vs. /shík^{h}è/	29	85	270.561	0.000***
/jīkè/ vs. /jīk^{h}ě/	32	85	60.865	0.001**
/kǔké/ vs. /kùk^{h}è/	38	86	120.844	0.000***

* *p*<0.05; ** *p*<0.01; *** *p*<0.001, ns: not significant

3.6. V2

Repeated measures ANOVAs showed that V2 in 13 word pairs was significantly longer after unaspirated stops (see Table 7). Another pair (/tìtài/ vs. /tǐt^{h}ài/), which did not significantly differ in V2, also had the same trend: V2 (/ài/) was longer after /t/ (177 ms) than after /t^{h}/ (151 ms). Those results lead to a compensatory relationship between VOT and the following V, which could be the reason why VOT is often regarded as part of the following vowel.

Table 7. V2: Averages (ms), *F* ratios, *p*-values

Word	N.Asp	Asp	*F*(1, 4)	*p*-value
/lǎopó/ vs. /lǎop^{h}ó/	171	144	156.312	0.000***
/gēpó/ vs. /gēp^{h}ò/	145	146	0.03	0.87 ns
/gépì/ vs. /gép^{h}í/	151	125	356.095	0.000***
/qīpiàn/ vs. /qīp^{h}iàn/	205	173	41.666	0.003**
/gǎipiàn/ vs. /gàip^{h}iàn/	200	168	23.387	0.008**
/pǔtōŋ/ vs. /pǔt^{h}ōŋ/	198	173	64.94	0.001**
/qítǎo/ vs. /qít^{h}ǎo/	169	144	10.492	0.032*
/miǎntiàn/ vs. /miǎnt^{h}iǎn/	193	153	14.103	0.02*
/shěŋtào/ vs. /shéŋt^{h}ào/	185	151	28.992	0.006**
/tìtài/ vs. /tǐt^{h}ài/	177	151	4.183	0.11 ns
/tóukǎo/ vs. /tóuk^{h}ào/	169	145	11.754	0.027*
/guókē/ vs. /guòk^{h}è/	161	136	36.527	0.004**
/shīkē/ vs. /shík^{h}è/	170	142	91	0.001**
/jīkè/ vs. /jīk^{h}ě/	171	126	18.193	0.013*
/kǔké/ vs. /kùk^{h}è/	171	139	16.739	0.015*

* $p<0.05$; ** $p<0.01$; *** $p<0.001$; ns: not significant

3.7. VOT2+V2

Statistical analyses proved that VOT2+V2 in 12 pairs was significantly longer when the intervocalic stop is aspirated than unaspirated (see Table 8). In the other three pairs also, VOT2+V2, if not significant, was longer after an aspirated stop. This means that the opposite durational variations of VOT and V2 only partly compensate for each other.

Table 8. VOT2+V2: Average (ms), *F* ratios, *p*-values

Word	N.Asp	Asp	*F*(1, 4)	*p*-value
/lǎopó/ vs. /lǎop^{h}ó/	187	216	27.238	0.006**
/gēpó/ vs. /gēp^{h}ò/	154	209	356.258	0.000***
/gépì/ vs. /gép^{h}í/	164	211	15.45	0.017*
/qīpiàn/ vs. /qīp^{h}iàn/	214	245	159.477	0.000***
/gǎipiàn/ vs. /gàip^{h}iàn/	207	238	178.332	0.000***
/pǔtōŋ/ vs. /pǔt^{h}ōŋ/	209	239	17.016	0.015*
/qítǎo/ vs. /qít^{h}ǎo/	180	213	45.274	0.003**
/miǎntiàn/ vs. /miǎnt^{h}iǎn/	210	223	1.3	0.318 ns
/shěŋtào/ vs. /shéŋt^{h}ào/	196	225	57.236	0.002**
/tìtài/ vs. /tǐt^{h}ài/	188	224	11.729	0.027*
/tóukǎo/ vs. /tóuk^{h}ào/	190	224	35.999	0.004**
/guókē/ vs. /guòk^{h}è/	196	219	81.955	0.001**
/shīkē/ vs. /shík^{h}è/	199	227	92.769	0.001**
/jīkè/ vs. /jīk^{h}ě/	203	211	2.411	0.195 ns
/kǔké/ vs. /kùk^{h}è/	209	225	4.862	0.092 ns

* $p<0.05$; ** $p<0.01$; *** $p<0.001$; ns: not significant

3.8. Word duration

Repeated measures ANOVAs yielded that words with an intervocalic aspirated stop were significantly longer than those with its unaspirated cognate in eight pairs (see Table 9). The other seven pairs also generated a little longer word durations when the intervocalic stop is aspirated. In Korean, the feature tenseness causes significant differentials between tense and lax stop closure durations, and the differentials contribute to significant durational differences between words with tense/lax intervocalic stops (Yun, 2010). In Chinese, VOT following intervocalic stop closure functions like Korean stop closure though its effect on word duration is not so strong or consistent as Korean stop closure.

Table 9. Word duration: Averages (ms), *F* ratios, *p*-values

Word	N.Asp	Asp	*F*(1, 4)	*p*-value
/lǎopó/ vs. /lǎop^{h}ó/	466	488	13.78	0.021*
/gēpó/ vs. /gēp^{h}ò/	440	491	101.119	0.001**
/gépì/ vs. /gép^{h}í/	446	474	4.412	0.104 ns
/qīpiàn/ vs. /qīp^{h}iàn/	517	523	0.624	0.474 ns
/gǎipiàn/ vs. /gàip^{h}iàn/	473	502	13.079	0.022*
/pǔtōŋ/ vs. /pǔt^{h}ōŋ/	481	489	0.73	0.441 ns
/qítǎo/ vs. /qít^{h}ǎo/	462	479	13.185	0.022*
/miǎntiàn/ vs. /miǎnt^{h}iǎn/	517	519	0.012	0.917 ns
/shěŋtào/ vs. /shéŋt^{h}ào/	494	516	30.344	0.005**
/tìtài/ vs. /tǐt^{h}ài/	461	477	0.743	0.437 ns
/tóukǎo/ vs. /tóuk^{h}ào/	466	494	37.851	0.004**
/guókē/ vs. /guòk^{h}è/	476	491	9.615	0.036*
/shīkē/ vs. /shík^{h}è/	493	522	10.719	0.031*
/jīkè/ vs. /jīk^{h}ě/	463	474	7.398	0.053 ns
/kǔké/ vs. /kùk^{h}è/	467	471	0.188	0.687 ns

* $p<0.05$; ** $p<0.01$; *** $p<0.001$, ns: not significant

As seen in the previous sections, the preceding vowel (VOT1)+V1 and the following intervocalic consonant C2 were generally longer when the stop is unaspirated, and so was their sum (VOT1)+V1+C2. In addition, V2 after VOT2 was generally longer when the intervocalic stop is unaspirated. Thus, the durational units before and after VOT2 varied to reduce the differences between VOT2s of unaspirated/aspirated stops. Nevertheless, words with an intervocalic aspirated stop were often significantly longer than those with its unaspirated cognate. It suggests that VOT2 is crucial to word duration in Chinese.

4. Summary and Conclusion

This study compared 15 pairs of bi-syllabic Chinese words with intervocalic unaspirated/aspirated stops to verify whether Chinese has the preconsonantal vowel shortening that is observed in many languages. The results were (1) preceding vowel shortening hardly occurred as a function of the feature aspiration of the following stop, (2) the following unaspirated stop closure (C) was similar to or longer than its aspirated cognate, (3) the preceding vowel duration (VOT1)+V1 and the following intervocalic stop closure duration C2 had no compensatory relationship unlike in other languages, e.g., Korean, English, Japanese, and Arabic where a long preceding vowel is followed by a short stop closure and vice versa. Rather, both the preceding vowel and the following stop closure tended to be longer when the intervocalic stop is unaspirated; so, the sum of the vowel duration and closure duration was also longer when the stop is unaspirated, (4) VOT2 was significantly longer when the stop is aspirated than when unaspirated, (5) V2 following VOT2 was significantly longer when the intervocalic stop is unaspirated, and it partly compensated for the differential between VOT2s before V2, (6) despite the partial compensation, VOT2+V2 was longer when the intervocalic stop is aspirated, (7) words with an intervocalic aspirated stop were longer than those with its unaspirated cognate though the differences were not always significant. This implies that the longer aspiration (VOT2) in words with an aspirated stop was not well absorbed by the other components of the words. Considering all, we can say that while VOT is the most important factor for deciding the timing structure of Chinese words with intervocalic stops, closure duration is crucial for Korean and many other languages. The language specific pattern of the preconsonantal vowel shortening should be incorporated into the phonology of Chinese.

On the other hand, Chinese stops seem to be all tense as well as voiceless. First, impr essionistically Chinese unaspirated stops sound like Korean tense unaspirated stops, while Chinese aspirated stops sound like Korean tense aspirated stops. Second, Chinese unaspirated/aspirated stops were often similar in duration though unaspirated stops were sometimes longer. Third, the effects of the following unaspirated/aspirated stops on the preceding vowel (VOT1)+V1 were generally similar, i.e., the duration of (VOT1)+V1 remained similar irrespective of the feature of the following stops. Therefore, if duration is a realization of utterance energy, Chinese unaspirated/aspirated stops are likely to have a similar degree of tenseness. Of course, whether Chinese stops are all tense or not, the feature tenseness does not distinguish Chinese stops as voicing does not.

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