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

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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 consonant closures and their voiceless cognates 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, t, k/) 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. 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 different 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.

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'/, which were similar in duration, were longer than /mamp'/i. Yun (2004) also showed that /ap'a/ and /ap'a/, 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'/, five pairs with alveolar stops /t, t'/; five pairs with velar stops /k, k'/) have one of Chinese unaspirated/aspirated stops (/p, p, t, t, k, k/) at the onset of the second syllable. The target words were embedded in a carrier sentence, 请把 ______ 再说一遍 [qiān 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

| Word | V1: Averages (ms), F ratios, p-values |
|------|-------------------------------------|
| /ľ̂ăp/or vs. /ľ̂ăp/ű̀| 157 149 10.441 0.032* |
| /gę̄p̄ṓ/ vs. /gę̄p̄ṓ/uję́| 151 145 1.751 0.256 ns |
| /ę̄ḡę̄/ vs. /ę̄ḡę̄/ų́| 146 139 1.551 0.281 ns |
| /ę̄p̄ń'/ vs. /ę̄p̄ń'/ų́| 91 79 9.131 0.039* |
| /ę̄p̄ń'/ vs. /ę̄p̄ń'/ű́| 147 156 4.058 0.114 ns |
| /ń̄ę̄ść̄/ vs. /ń̄ę̄ść̄/ų́| 94 88 2.025 0.228 ns |
| /ę̄ń̄ą́/ vs. /ę̄ń̄ą́/ų́| 84 39 0.109 0.758 ns |
| /ń̄ę̄ść̄/ vs. /ń̄ę̄ść̄/ų́| 187 186 0.012 0.918 ns |
| /ę̄ń̄ą́/ vs. /ę̄ń̄ą́/ų́| 156 156 0.002 0.97 ns |
| /ń̄ę̄ść̄/ vs. /ń̄ę̄ść̄/ų́| 95 79 3.143 0.151 ms |
| /ń̄ę̄ść̄/ vs. /ń̄ę̄ść̄/ų́| 139 126 7.1 0.056 ns |
| /ę̄ń̄ą́/ vs. /ę̄ń̄ą́/ų́| 156 144 3.553 0.133 ms |
| /ń̄ę̄ść̄/ vs. /ń̄ę̄ść̄/ų́| 97 94 0.545 0.501 ms |
| /ę̄ń̄ą́/ vs. /ę̄ń̄ą́/ų́| 101 113 2.389 0.197 ms |
| /ń̄ę̄ść̄/ vs. /ń̄ę̄ść̄/ų́| 133 123 4.14 0.112 ms |

2.3. Measurement and statistics

First, we measured the 1st syllable duration - when the onset is a lateral /ń̄/: /ń̄/ + 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., /ń̄̄ę̄/-/ń̄̄ę̄̄/: C1 + affrication (for convenience it is calculated as VOT1) + V1; when the onset is a fricative (e.g., /ń̄̄ę̄/-/ń̄̄ę̄̄/: VOT + closure duration + V1 (for convenience the coda /ń̄̄/ was counted as part of V1); when the onset is a nasal (e.g., /ń̄̄ą́/): nasal duration + V1 (for convenience the final /ń̄̄/ 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 /ń̄, ń̄̄/ were counted as part of V2). Finally, the whole word duration was measured.

We obtained averages (ms), SD, SE, and 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 = 0.022, 0.039). Furthermore, some vowels were longer before aspirated stops (e.g., /ę̄ń̄ą́/ 147 ms vs. /ę̄ń̄ą́/ų́/ 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.

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., /ę̄ń̄ą́/ (163 ms) vs. /ę̄ń̄ą́/ų́/ (172 ms); /ń̄ę̄ść̄/ (165 ms) vs. /ń̄ę̄ść̄/ų́/ (174 ms), and one pair had the same length, i.e., /ń̄ę̄ść̄/ (156 ms) vs. /ń̄ę̄ść̄/ų́/ (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.

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. /gēpó/ (45 ms); /tí/tí' (37 ms) vs. /tí/tí' (41 ms); /tóukáó/ (30 ms) vs. /tóukáó/ (32 ms)), or the same in one pair (/lǎopó/ (60 ms) vs. /lǎopó/ (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.As | Asp | F(1, 4) | p-value |
|------------------|------|-----|---------|---------|
| /lǎopó/ vs. /lǎopó/ | 60   | 60  | 0.000   | 0.964 ns |
| /gēpó/ vs. /gēpó/  | 41   | 45  | 0.000   | 0.964 ns |
| /gēpó/ vs. /gēpó/  | 46   | 40  | 5.558   | 0.078 ns |
| /qǐfán/ vs. /qǐfán/ | 45   | 37  | 5.247   | 0.084 ns |
| /gǎipán/ vs. /gǎipán/ | 40   | 38  | 16.64   | 0.015    |
| /pǔtō/ vs. /pǔtō/  | 42   | 31  | 89.342  | 0.001**  |
| /qǐtāo/ vs. /qǐtāo/ | 36   | 28  | 12.512  | 0.024    |
| /mǎintián/ vs. /mǎintián/ | 35   | 21  | 18.27   | 0.013    |
| /shèngtào/ vs. /shèntào/ | 32   | 22  | 15.861  | 0.016    |
| /nítài/ vs. /nítài/ | 37   | 41  | 2.204   | 0.121 ns |
| /kǔkě/ vs. /kǔkě/  | 30   | 32  | 0.5     | 0.518 ns |
| /gǔkě/ vs. /gǔkě/  | 41   | 36  | 7.115   | 0.056 ns |
| /šīkě/ vs. /šīkě/  | 41   | 38  | 1.064   | 0.361 ns |
| /jǐkè/ vs. /jǐkè/  | 51   | 39  | 3.882   | 0.12 ns  |
| Asp vs. /kǔkě/    | 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 (/gēpó/ vs. /gēpó/, p = 0.061; /gǎipán/ vs. /gǎipán/, p > 0.1). 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.As | Asp | F(1, 4) | p-value |
|------------------|------|-----|---------|---------|
| /lǎopó/ vs. /lǎopó/ | 216  | 208 | 1.496   | 0.288 ns |
| /gēpó/ vs. /gēpó/  | 223  | 220 | 0.515   | 0.015 ns |
| /gěpó/ vs. /gěpó/  | 225  | 210 | 6.722   | 0.001**  |
| /qǐfán/ vs. /qǐfán/ | 264  | 238 | 0.726   | 0.015 ns |
| /gǎipán/ vs. /gǎipán/ | 223  | 209 | 6.685   | 0.001**  |
| /pǔtō/ vs. /pǔtō/  | 213  | 194 | 21.424  | 0.017    |
| /qǐtāo/ vs. /qǐtāo/ | 242  | 226 | 100.829 | 0.001**  |
| /mǎintián/ vs. /mǎintián/ | 222  | 207 | 11.768  | 0.027**  |
| /shèngtào/ vs. /shèntào/ | 189  | 178 | 47.045  | 0.002**  |
| /nítài/ vs. /nítài/ | 223  | 214 | 2.185   | 0.189 ns |
| /kǔkě/ vs. /kǔkě/  | 239  | 231 | 5.026   | 0.042*   |
| /gǔkě/ vs. /gǔkě/  | 227  | 209 | 0.875   | 0.304 ns |
| /shīkě/ vs. /shīkě/ | 138  | 132 | 1.137   | 0.346 ns |
| /jǐkè/ vs. /jǐkè/  | 216  | 213 | 7.25    | 0.055 ns |
| Asp vs. /kǔkě/    | 206  | 185 | 27.904  | 0.006**  |

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

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'/ 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.As | Asp | F(1, 4) | p-value |
|------------------|------|-----|---------|---------|
| /lǎopó/ vs. /lǎopó/ | 66   | 72  | 0.857   | 0.391 ns |
| /gēpó/ vs. /gēpó/  | 9    | 64  | 170.585 | 0.000*** |
| /gěpó/ vs. /gěpó/  | 13   | 87  | 39.983  | 0.003**  |
| /qǐfán/ vs. /qǐfán/ | 9    | 72  | 135.903 | 0.000*** |
| /gǎipán/ vs. /gǎipán/ | 7    | 70  | 144.501 | 0.000*** |
| /pǔtō/ vs. /pǔtō/  | 11   | 66  | 106.699 | 0.000*** |
| /qǐtāo/ vs. /qǐtāo/ | 11   | 69  | 43.268  | 0.003**  |
| /mǎintián/ vs. /mǎintián/ | 17   | 69  | 502.84  | 0.000*** |
| /shèngtào/ vs. /shèntào/ | 11   | 74  | 67.38   | 0.001*** |
| /nítài/ vs. /nítài/ | 11   | 72  | 36.75   | 0.004    |
| /kǔkě/ vs. /kǔkě/  | 22   | 79  | 55.11   | 0.002    |
| /gǔkě/ vs. /gǔkě/  | 34   | 83  | 76.128  | 0.001*** |
| /shīkě/ vs. /shīkě/ | 29   | 85  | 270.561 | 0.000*** |
| /jǐkè/ vs. /jǐkè/  | 32   | 85  | 60.865  | 0.001*** |
| Asp vs. /kǔkě/    | 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. /tǐtài/), which did not significantly differ in V2, also had the same trend: V2 (/ǎi/) was longer after /u/ (177 ms) than after /u/ (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 |
|-----------------------|-------|-----|---------|---------|
| /tìtài/ vs. /tǐtài/   | 145   | 146 | 0.03    | 0.87 ns |
| /gēpì/ vs. /gēpì/    | 151   | 125 | 356.095 | 0.000  |
| /qǐtǎn/ vs. /qǐtǎn/  | 205   | 173 | 41.666  | 0.003  |
| /shǐkē/ vs. /shíkē/  | 200   | 168 | 23.387  | 0.008  |
| /pùtōŋ/ vs. /pùtōŋ/ | 198   | 173 | 64.94   | 0.001  |
| /qǐtāo/ vs. /qǐtǎo/  | 169   | 144 | 10.492  | 0.032  |
| /mǐntān/ vs. /mǐntǎn/| 193   | 153 | 14.103  | 0.02   |
| /shènțào/ vs. /shéntào/ | 185 | 151 | 28.992  | 0.006  |
| /qǐtāo/ vs. /qǐtāo/  | 177   | 151 | 4.183   | 0.11 ns |
| /tōukǎo/ vs. /tōukào/| 169   | 145 | 11.754  | 0.027  |
| /jiēkē/ vs. /jiēkē/ | 161   | 136 | 36.527  | 0.004  |
| /jiēkē/ vs. /jiēkē/ | 170   | 142 | 91      | 0.001  |
| /Ākē/ vs. /Ākē/     | 171   | 126 | 18.193  | 0.013  |
| /Ākē/ vs. /Ākē/     | 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 after unaspirated stops (see Table 7). In the other three pairs also, VOT2+V2 was significantly longer when the intervocalic stop is aspirated than when unaspirated, and so was their sum (VOT1)+V1+C2. Nevertheless, words with an intervocalic aspirated stop are often 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 |
|-----------------------|-------|-----|---------|---------|
| /tìtài/ vs. /tǐtài/   | 145   | 146 | 0.03    | 0.87 ns |
| /gēpì/ vs. /gēpì/    | 151   | 125 | 356.095 | 0.000  |
| /qǐtǎn/ vs. /qǐtǎn/  | 205   | 173 | 41.666  | 0.003  |
| /shǐkē/ vs. /shíkē/  | 200   | 168 | 23.387  | 0.008  |
| /pùtōŋ/ vs. /pùtōŋ/ | 198   | 173 | 64.94   | 0.001  |
| /qǐtāo/ vs. /qǐtǎo/  | 169   | 144 | 10.492  | 0.032  |
| /mǐntān/ vs. /mǐntǎn/| 193   | 153 | 14.103  | 0.02   |
| /shènțào/ vs. /shéntào/ | 185 | 151 | 28.992  | 0.006  |
| /qǐtāo/ vs. /qǐtāo/  | 177   | 151 | 4.183   | 0.11 ns |
| /tōukǎo/ vs. /tōukào/| 169   | 145 | 11.754  | 0.027  |
| /jiēkē/ vs. /jiēkē/ | 161   | 136 | 36.527  | 0.004  |
| /jiēkē/ vs. /jiēkē/ | 170   | 142 | 91      | 0.001  |
| /Ākē/ vs. /Ākē/     | 171   | 126 | 18.193  | 0.013  |
| /Ākē/ vs. /Ākē/     | 171   | 139 | 16.739  | 0.015  |
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.

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, impressionistically 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 of the following unaspirated/aspirated stops on the preceding vowel though unaspirated stops were sometimes longer. Finally, the effects of the following unaspirated/aspirated stops on the preceding vowel (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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