Acoustic Effects of Consonant Positions on Vowels in Monguor Language

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ABSTRACT: The purpose of the study is to discuss acoustic effects of consonant positions on monophthongs in Monguor language and whether the preceding and the subsequent consonants have the same effect on the coarticulation COD of monophthongs. This paper concludes that both in the CV structure and in the VC structure, the monophthongs with the tongue back, the tongue high, and the lip round are more likely to be influenced by their preceding or subsequent consonants. In addition, the lower the tongue, the smaller the coarticulation COD of vowels.

1. INTRODUCTION
Suprasegmental features include the syllable, the stress, the tone, and the intonation. In Monguor language, a small number of studies have recently discussed these features from the acoustic perspective. Dwyer (2008) has identified a default pitch rises on word boundaries in Monguor language. Pitch, accent or stress can accordingly be realized by the tonal melodies. Stress is placed on the last syllable of a word, and a raised F0 appears on the word’s spectrogram. Additionally, because of the language development over time, the loss of segments may sometimes lead to homophony. A high tone and a low tone can make two words distinctive. Those words can be well distinguished on acoustic analysis. Jatteau and Hejná (2018) explore the gradual phonetic change applying the acoustic spectrogram. They find that some phonetics changes should result from lexical diffusion. They compare Monguor language with Mongolian. Mongolian is noted for gradient dissimilation of the aspiration feature. Their results suggest that Monguor language and Mongolian have different patterns in the aspirated stops.

Chinese researchers have paid attention to acoustic study on Monguor language in recent years. Jiang Genxiong (2013) discusses the short vowel parameters of the first syllable of the Monguor words from the acoustic point of view; Han Guojun and Huhe (2013) also analyze the short vowel acoustic parameters of the Monguor words. Han Guojun (2013, 2016) combs the phonology of the Monguor language from the acoustic point of view. Zhang carries on acoustic analysis of nasal vowels (2017a) and Monophthongs (2017b) in Monguor Language.

A lot of research by Zhang is about coarticulation of speech in Monguor Language. Zhang introduces the concept of dispersion to measure the degree of coarticulation. Zhang (2017c) measures the coarticulatory dispersion in NCV Sequences in Monguor Language. The study mainly discusses the coarticulatory dispersion of places of articulation of affricates, the coarticulatory dispersion of...
voiced and voiceless affricates, and the main effects of places of articulation of affricates, voiced and voiceless affricates on coarticulatory dispersion. The following studies discuss the coarticulation of nasal vowels (Zhang, 2017d) and triphthongs (Zhang, 2018a). The former discusses the differences in the coarticulatory dispersions between the nasal vowels [ɑ̃] and [ɔ̃] and the locus equation slopes of the unaspirated stops by the following nasal vowels [ɑ̃] and [ɔ̃]. The latter discusses the transitional modes for triphthongs in Monguor language and whether the preceding consonants have significant effect on the transitional modes of triphthongs. Another research models the coarticulation of consonants in Monguor Language (Zhang, 2018b). This study discusses, of the acoustic features of consonants: F1, F2, F3, the length and intensity of consonants, which have significant linear relation with coarticulation dispersion in Monguor language. The result shows that a linear relationship exists only between F2 and the coarticulation dispersion of the Monguor consonants. The above research is all based on the acoustic parameters.

This study focuses on one of the suprasegmental features and discusses the coarticulation in a syllable, without considering the coarticulation cross adjacent syllables.

2. METHOD

2.1 Source of Corpus
An acoustic parameter database of the Monguor speech provides the data used in this study. The Monguor words of elaborate record came from Monguor people of Tianshu County in Gansu Province of China. The words retrieved from the database for this study are those of containing vowel-only (V) syllables, consonant-vowel (CV) syllables, and vowel-consonant (VC) syllables.

2.2 Speech Signal Collection
In consideration of language stability, the informants for the study are thirteen male speakers, about 40 to 60. The informants are teachers in local primary or junior schools. Their speeches are similar to Huzhu dialect (in Qinghai Province). This study employs a Dell Notebook, a microphone of Behringer, and a sound card of YAMAHA Steinberg as the recording equipment. The sound is recorded in a recording studio with a sampling rate 44.1 kHz and resolution ratio 16 bits. The recording is saved with *wav. Each word is read three times by each speaker, and the researcher gets a sample of 39.

2.3 Measurement of coarticulation
Acoustic effect will be measured with coarticulation between a consonant and a vowel in a syllable. The degree of coarticulation will be measured with dispersion. In this study, the parameter of coefficient of dispersion (COD) is applied for the measurement of dispersion. COD is the ratio of the average absolute deviation from the median to the median of the data. The formula of COD is:

\[ \text{COD} = \frac{\sum |R_i - \bar{R}|}{N \times M} \]

In (1) R is the ratio of F2_{target} (the target value of the second formant) to F2_{onset} (the onset value of the second formant); \( R_i \) is each ratio value; \( \bar{R} \) is the mean of all ratio values; N is the number of the sample; and M is the median of all ratio values. In this study, COD is calculated by putting the values of F2_{target} and F2_{onset} into SPSS22.0.

2.4 Research Questions
This study will address the following questions:
(1) In Monguor language, what are the values of COD for V, CV and VC?
(2) What are the acoustic Effects of consonant positions on vowels?
3. RESULTS AND DISCUSSION

3.1 Values of COD for V, CV and VC

Each word recorded is read three times by each speaker, so this study has a sample of 39 for each word. This study has got the descriptive statistical results of the coarticulation COD for five monophthongs a(a), e(e), i(i), o(o), and u(u) combined with all consonants in CV syllables. Here while a is the short vowel, aa is the long vowel. From the aspect of the mean of COD, the mean of the three monophthongs a(a), e(e), and i(i) are very close (0.099, 0.109, 0.103), all around 0.1. The mean values of o(o) and u(u) are very close (0.203, 0.188), both near 0.2. The mean of COD for o(o) is the largest, and the mean of COD for a(a) is the smallest. The standard deviation (SD) (0.011-0.014) and standard error(approximately 0.002) of the five monophthongs in coarticulation COD are very close, indicating that the variations of the five monophthongs in coarticulation COD are basically the same.

The VC syllable only appears at the beginning of a word or forms an independent word. The monophthong e(e) does not appear at the beginning of a word in Monguor language; therefore, there is no monophthong e(e) in the VC structure. The other four monophthongs a(a), i(i), o(o), and u(u) have a limited number of combinations in the VC structure. Of the 4,844 Monguor words collected by the researcher, the combinations of vowel a(a) with consonants in the VC structure are: al, am, an, ar, as, ax; the combinations of vowel i(i) with consonants in the VC structure are: iil, im, in, is, ish; the combinations of the vowel o(o) in the VC structure are: om, oor, oos, or; the combinations of the vowel u(u) in the VC structure are: ul, un, ur.

The coarticulation COD of the VC structure is compared with that of the vowel-only V structure and that of the CV structure. The purpose is to explore whether consonants located after a vowel and before the vowel have the same acoustic effect on the vowel pronunciation. The means of the coarticulation COD for a(a), i(i), o(o), and u(u) in the V structure are 0.068 (SD 0.008), 0.069 (SD 0.009), 0.127 (SD 0.013) and 0.116 (SD 0.011) respectively; those in the CV structure are 0.099 (SD 0.014), 0.103 (SD 0.011), 0.203 (SD 0.014) and 0.188 (SD 0.011) respectively; and those in the VC structure are 0.080 (SD 0.010), 0.090 (SD 0.009), 0.178 (SD 0.013) and 0.163 (SD 0.022) respectively (Table 1).

It can be seen that the mean coarticulation COD of the four monophthongs combined with preceding consonants or subsequent consonants is greater than that of V structure (mean 0.095, SD 0.029), and the mean coarticulation COD of the CV structure (mean 0.148, SD 0.049) is greater than that of the VC structure (mean 0.128, SD 0.046), which shows that preceding or subsequent consonants have a certain influence on the acoustic features of vowels.

|                      | V       | VC      | CV       |
|----------------------|---------|---------|----------|
| M        | 0.068   | 0.080   | 0.095    |
| SD       | 0.008   | 0.010   | 0.029    |
| N        | 39      | 39      | 156      |

Note: M=mean
SD=standard deviation
N=number

3.2 Acoustic Effects of Consonant Positions on Vowels

In this experiment, a Two-way ANOVA model is adopted. One of the factors in the model is the syllable types, which are VC syllable structure, CV syllable structure, and V syllable structure. Another factor in the model is monophthongs. That is, the four variables a(a), i(i), o(o), and u(u). The
dependent variable is the coarticulation COD. The purpose of the experiment is to discuss the influence of different syllable types and different monophthongs on the coarticulation COD and whether different syllable types and different monophthongs have an interaction effect on the coarticulation COD.

Table 2. Results of the ANOVA model

| Sources            | Type III Sum of Squares | df | Mean Square | F       | P    |
|--------------------|-------------------------|----|-------------|---------|------|
| Corrected Model    | .945                    | 5  | 0.189       | 794.539 | .000 |
| Intercept          | 7.161                   | 1  | 7.161       | 3.010E4 | .000 |
| Syllable types     | 0.227                   | 2  | 0.114       | 477.732 | .000 |
| Monophthongs       | 0.718                   | 3  | 0.239       | 1.006E3 | .000 |
| Error              | 0.110                   | 462| .000        |         |      |
| Total              | 8.216                   | 468|             |         |      |
| Corrected Total    | 1.055                   | 467|             |         |      |

The results of the ANOVA model (Table 2) show that of the total variance (8.216), the square sum of the intercept is 7.161, the square sum of the syllable types 0.227, and the square sum of monophthongs 0.718. The error of the square sum is 0.110. In practical applications, the independent variable will not be 0, while the intercept represents the value of the dependent variable when the independent variable is 0. The intercept item is accordingly corrected in the model. That is, the total square sum of the corrected model = the square sum of the corrected model (syllable types + monophthongs) + error of the square sum. It can be seen that in the corrected model, of the total variance (1.055), the main variance comes from the corrected model (0.945), and the variance from the error is smaller. The F value of the corrected model is 794.539 and the P value is 0.000 < 0.05, which shows that this model is effective in the analysis of variance of the two factors.

In this experimental model, that the F value of the syllable type factor is 477.732 and the P value is 0.000 < 0.05, indicates that there are significant differences between the variables in the syllable types. The multiple comparisons of the COD between syllable types (Table 3) show that a significant level P value appears in either pair. That is, all P values are less than 0.05, indicating that there are significant differences between the variables of the syllable types. The order of the coarticulation COD is CV structure, VC structure, and V structure from large to small, which indicates the different degrees of the influence of preceding consonants and subsequent consonants on the coarticulation COD of monophthongs. The preceding consonants have a greater effect on the coarticulation COD of monophthongs than the subsequent consonants.

Table 3. Multiple comparisons between syllable types

|        | V   | VC  |
|--------|-----|-----|
| VC     | .000|     |
| CV     | .000| .000|

In this experimental model, the F value of the monophthong factor is 1.006×103 and the P value is 0.000 < 0.05, which indicates that there are significant differences between the variables in the monophthong variables. The multiple comparisons of the COD between monophthongs (Table 4) show that there is no significant difference between the units a(a) and i(i) (P = 0.183 > 0.05), while there are significant differences between the remaining two variables.
Table 4. Multiple comparisons between monophthongs

|     | a  | i  | o  |
|-----|----|----|----|
| i   | .183 |    |    |
| o   | .000 | .000 |    |
| u   | .000 | .000 | .015 |

The distribution of the coarticulation COD in CV structure, VC structure and V structure (in Figure 1) shows that there exist interactions among the monophthong variables except between o(o) and u(u) because of the two parallel trends. That is, different syllable types and different monophthongs, except between o(o) and u(u), have an interaction effect on the coarticulation COD. Each monophthong has the smallest COD in the V syllable structure, the slightly larger COD in the VC syllable structure, and the largest COD in the CV syllable structure. The order of the coarticulation COD for the four monophthongs is: o(o) > u(u) > i(i) > a(a). While the coarticulation CODs between a(a) and i(i) and between o(o) and u(u) are close, the CODs for a(a) and i(i) are relatively small, and those for o(o) and u(u) are relatively large.

Example of the F2 distribution of VC and CV structures in Figure 2 are certain syllables of the following Monguor vocabulary: argu (mother-in-law), orqin (environment), urna (west), nara (Sun), xuroogun (lunch), yuruu (chin). In the syllable “ar”, the F2 of a is almost not affected by the subsequent consonant r, while in the syllable “ra”, the F2 of a is significantly affected by its preceding consonant r. In the syllable “or”, o’s F2 is also almost not affected by the subsequent consonant r, while in the syllable “roo”, oo’s F2 is significantly affected by its preceding consonant r. In the syllable “ur”, u’s F2 is slightly increased by the influence of the subsequent consonant r, while in the syllable “ruu”, uu’s F2 is significantly weakened by the influence of its preceding consonant r.
4. **CONCLUSION**

It can be seen that both in the CV structure and in the VC structure, the vowels with the tongue back, the tongue high, and the lip round have a large coarticulation COD, indicating that such vowels are more likely to be influenced by their preceding or subsequent consonants. The influence of preceding consonants is even greater. The coarticulation COD of vowels with the tongue front, the tongue middle, and the lip wide is relatively small, indicating that such vowels are less affected by their preceding or subsequent consonants and are relatively stable, while the influence of their preceding
consonants is greater. Relatively speaking, the lower the tongue, the smaller the coarticulation COD of vowels.

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