Coarticulation of Triphthongs in Monguor Language

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Abstract. The purpose of the study is to discuss the transitional modes for triphthongs in Monguor language and whether the preceding consonants have significant effect on the transitional modes of triphthongs. This paper concludes that the change rates of the first parts for F1 or F2 are higher than those of the second parts, and the first parts for F1 or F2 are the transitional segments, and the second parts for F1 or F2 stable segments. In addition, the preceding consonants have significant effect on the transitional modes of triphthongs from the perspective of change rates.

1. Introduction
Triphthong, also known as the middle-loud vowel, is composed of three vowels. The vowels in the middle are the loudest, and the vowels at both ends are shorter and weaker. There are four triphthongs in mandarin: /iao/, /iou/, /uai/, and /uei/. In English, the number of triphthongs appearing in a syllable is small, such as [aʊə] in flour, [aɪə] in fire, [ɪəʊ] in radio, [ɔɪə] in loir. However, three-letter combination has the diphthong pronunciation, such as [əʊ] in plateau, [ia] in serious. In Monguor Language, there are only two triphthongs: /iau/ and /uai/.

The studies on the coarticulation in Monguor language focus on the coarticulatory dispersion. The dispersion is calculated with the equation \( \text{COD}=\frac{\sum (R_i-\bar{R})}{(N\times M)} \), in which \( R \) is the ratio of \( F_2 \) target to \( F_2 \) onset, \( \bar{R} \) the mean of all ratio values, \( N \) the number of the sample, and \( M \) the median of all ratio values. Zhang (2017a) studies the articulatory dispersion in NCV sequences via measuring out the onset and the target values of \( F_2 \) in the second formant transitions of vowels. In NCV sequences, \( N \) refers to the nasal /n/, \( C \) to the affricates [ts, tsʰ, tʂ, tʂʰ, tɕ, tɕʰ], \( V \) to the vowels. The order of the coarticulatory dispersion of from the lowest to the highest is: [nts] < [ntsʰ] < [ntɕ] < [nts] < [ntɕʰ] < [ntɕʰ]. Based on the acoustic parameter database of the Monguor speech, the study (Zhang, 2017b) on the coarticulation of nasal vowels shows that the coarticulatory dispersion of [æ] is significantly higher than that of [ɔ]. Besides, the study discusses the coarticulation by means of the locus equation slope and comes to the conclusion the slope of the velar is the highest, and that of the apical is the lowest.

The coarticulation can also be embodied by the acoustic features of speech. With the aid of the acoustic parameter database of Monguor speech, Zhang (2017c) discusses the acoustic features of the nasal vowels [æ] and [ɔ]. The study finds out that the duration of the nasal vowel [ã] or the nasal vowel [ɔ] can be predicted by its F1, F2 and F3 respectively. In another study, Zhang (2017d) analyzes the differences in duration and F2 between short and long monophthongs and those in first syllable, middle syllable(s), and last syllable for short and long monophthongs.

In other languages, coarticulation has been extensively discussed by means of descriptive phonetic measurements. Matthies et al. (2001) analyze the coarticulation of articulatory movements at VC and CV boundaries in English influenced by different speaking speed. They come to the conclusion that
the consonant-string duration was the longest in the clear speaking speed and the shortest in the fast speed. However, the influences of speaking speed on coarticulation and on the formants of /i/ are small. Whang (2018) discusses the effects of Phoneme predictability on the deletion of devoiced vowels in Japanese and finds that devoicing lengthens only non-fricatives, while it has either no effect or a shortening effect on fricatives. Chang et al. (2002) assess anticipatory coarticulation and F2 transition rate (FTR) of speech production in stuttered and normal children in English initial CV syllables and show the result that the FTR production for place of articulation is not as refined in stuttered children as in normal children because of the break of their speech fluency. Schatz et al. (2017) illustrate their methods of DTW-based similarity and ABX scores using stimuli in English and Japanese to prove that stronger anticipatory than perseveratory coarticulation and stronger coarticulation for lax/short vowels than for tense/long vowels.

2. Method

2.1. Source of corpus
The data used in this study came from an acoustic parameter database of the Monguor speech. The Monguor words recorded were collected from Monguor people of Gansu and Qinghai Provinces of China. The words containing triphthong are retrieved from the database.

2.2. Speech signal collection
Thirteen male speakers, aged from 40 to 60, read all the listing words. The speakers come from the local primary or junior schools. Their speeches belong 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
The syllable structure model of triphthong in Monguor language is CV1V2V3, which shows that a single consonant exists before triphthong in a syllable. However, the transitional modes among three vowels are complicated, such as the transitional modes among the three vowels /i-a-u/ in the word liauki- [liokʰa] (which means “burn”), which have three target articulator positions. The transitional modes for triphthong can be composed of the change rate of F1 or F2 from V1-V2 and V2-V3. The formula for calculating the change rate with the unit Hz/ms can be:

$$v = \frac{F_{\text{max}} - F_{\text{min}}}{L}$$

F_{\text{max}} is the biggest value for the transitional section V1-V2 or V2-V3 of F1 or F2. F_{\text{min}} is the smallest value for the transitional section V1-V2 or V2-V3 of F1 or F2. L is the duration of the transitional section V1-V2 or V2-V3 of F1 or F2.

2.4. Research questions
This study will address the following questions:

1. In Monguor language, what are the transitional modes for triphthongs?
2. Do the preceding consonants have significant effect on the transitional modes of triphthongs?

3. Results and discussion

3.1. Transitional modes for triphthongs
The coarticulation among V1V2V3 is realized via calculating the change rate of F1 or F2 from V1-V2 and V2-V3. There are only two triphthongs in Monguor language: iau and uai. A triphthong in Monguor language itself cannot be a syllable or a word, and it can form syllable or vocabularies with
anterior semi vowel y or w, such as yau-[iau](walk), yaudal-[iaudal](step), wai-[uai](have), waijin-[uaiʨin](rich).

The formant trends (Figure 1) of the triphthong /iau/ in Monguor language show that F1 or F2 of /iau/ has the clear transitional and stable segments; however, if each formant is divided into two parts with the maximum of F1 as the critical point, the obvious transitional and stable sections disappear.

Figure 1. The formants of the triphthong /iau/

The formant trends (Figure 2) of the triphthong /uai/ in Monguor language show that F2 of /uai/ has the clear transitional and stable segments. Though F1 of /uai/ has no clear transitional and stable segments, it also can be divided into two parts with the maximum of F1 as the critical point. So F1 and F2 of /uai/ can also be considered as having the obvious transitional and stable sections.

Figure 2. The formants of the triphthong /uai/

The triphthongs in Monguor language are the middle-loud complex vowels. When the tongue position of the middle sound [a] is the lowest, the transition to the last vowel takes place. Because F1 is the largest while the tongue position of [a] is the lowest (Wu & Lin, 2014), this paper will discuss the change rates of /ia/ and /au/ in /iau/, of /uai/ and /ai/ in /uai/, with the maximum of F1 as the critical point, and will compare the rates with those of the corresponding diphthongs. The triphthongs and the corresponding diphthongs must have the same preceding consonants.

In order to distinguish the divisions of triphthongs from diphthongs, this paper names the divisions of triphthongs as /iau₁/ and /iau₂/ for /ia/ and /au/ in /iau/, /uai₁/ and /uai₂/ for /uai/ and /ai/ in /uai/. When the triphthongs are individually pronounced, the change rates of the first formant and the second formant of the decomposed parts are as follows:

/iau₁/: \( v_{F1}=1.689 \), \( v_{F2}=3.938 \)

/iau₂/: \( v_{F1}=0.455 \), \( v_{F2}=0.610 \)

uai₁/: \( v_{F1}=1.555 \), \( v_{F2}=4.708 \)

uai₂/: \( v_{F1}=0.481 \), \( v_{F2}=0.831 \)

The change rates of the first parts for F1 or F2 are higher than those of the second parts. The first parts for F1 or F2 are the transitional segments, and the second parts for F1 or F2 are stable segments.

3.2. Effect of consonants on transitional modes in CVVV

The researcher has collected 4844 Monguor words, in which /iau/ appears only in 9 words with the first syllable, and 3 words with the second syllable; /uai/ appears in 3 words with all in the first syllable. The collected words with CVVV are listed in Table 1.
Table 1. Monguor words with triphthongs

| Monguor word | IPA       | Meaning                  |
|--------------|-----------|--------------------------|
| biau         | [piʊɔ]    | watch, clock             |
| diauja       | [tɪʊtɛː]  | Diao, Chinese family name|
| liauja       | [lɪʊtɛː]  | Liao, Chinese family name|
| liauki-      | [lɪʊtɔkʰə] | burn                     |
| miauzi       | [miʊotʂ]  | seedling, shoot          |
| piau         | [pʰiʊ]    | ticket                   |
| tiaupiila-   | [tʰiʊpʰiːlᴀ] | be naughty, be playful   |
| tiauzi       | [tʰiʊtsɿ] | strip, bar               |
| xiauzhang    | [ɕiʊtsɿ]  | headmaster               |
| daibiau      | [tʰaɪpʊo] | delegate, representative |
| funtiauzi    | [fʊntʰiʊtsɿ] | bean or potato noodles |
| shubiau      | [su:pʰiʊo] | watch worn on one’s wrist|
| guai-        | [kuaɪ]    | run, rush                |
| kuaaji       | [kʰuɑntʰɛɪ] | accountant              |
| xuaida-      | [ɕuaɪtʰᴀ] | shake off                |

The results of T-test (Table 2) show the differences of change rates of the divisions of triphthongs for F1 or F2. The comparison data of /iau1/ and /ia/ show that the change rate (2.145) of F1 for /iau1/ is significantly lower than that (3.850) of F1 for /ia/ (T=-11.593, P=0.000 < 0.05), while the dispersion degree of the change rate of F1 for /iau1/ is larger (/iau1/: SD 0.855, SEM 0.137; /ia/: SD 0.335, SEM 0.054). The change rate (4.513) of F2 for /iau1/ is the same as that (4.740) of F2 for /ia/ (T=-1.017, P=0.312 > 0.05), while the dispersion degree of the change rate of F2 for /iau1/ is larger (/iau1/: SD 1.387, SEM 0.143; /ia/: SD 0.222, SEM 0.023). The change rate (0.722) of F1 for /iau2/ is significantly lower than that (0.940) of F1 for /au/ (T=3.473, P=0.001 < 0.05), while the dispersion degree of the change rate of F1 for /iau2/ is larger (/iau2/: SD 0.380, SEM 0.061; /au/: SD 0.096, SEM 0.015). The change rate (1.990) of F2 for /iau2/ is significantly larger than that (0.628) of F2 for /au/ (T=11.116, P=0.000 < 0.05), and the dispersion degree of the change rate of F2 for /iau2/ is also larger (/iau2/: SD 0.742, SEM 0.119; /au/: SD 0.187, SEM 0.030).

Table 2. Comparisons of change rates

|       | F1   | F2   | F1   | F2   | F1   | F2   | F1   | F2   |
|-------|------|------|------|------|------|------|------|------|
| iau1  | 39   | 39   | 39   | 39   | 39   | 39   | 39   | 39   |
| ia    | 2.145| 3.850| 4.513| 4.740| 0.722| 0.940| 1.990| 0.628|
| uai1  | .855 | .335 | 1.387| 1.462| .742 | .187 | 1.080| .464 |
| uai   | .137 | .054 | .222 | .234 | .061 | .015 | .173 | .028 |
| ai    | 2.021| 1.888| 3.063| 3.302| .773 | .625 | 1.283| .554 |
| uai2  | .854 | .176 | 1.462| 1.462| .464 | .047 | .422 | .045 |
| ai    | .173 | .234 | .016 | .016 | .074 | .008 | .068 | .007 |
|       | .449 | .000 | .000 | .000 | .619 | .030 | .187 | .007 |

The comparison data of /uai1/ and /ua/ show that the change rate (2.021) of F1 for /uai1/ is the same as that (1.888) of F1 for /ua/ (T=0.760, P=0.449 > 0.05), while the dispersion degree of the change rate of F1 for /uai1/ is larger (/uai1/: SD 1.080, SEM 0.173; /ua/: SD 0.176, SEM 0.028). The change rate (3.063) of F2 for /uai1/ is significantly larger than that (2.146) of F2 for /ua/ (T=3.830, P=0.000 < 0.05), and the dispersion degree of the change rate of F2 for /uai1/ is also larger (/uai1/: SD 1.462, SEM 0.234; /ua/: SD 0.098, SEM 0.016). The change rate (0.773) of F1 for /uai2/ is the same as that (0.625) of F1 for /ai/ (T=1.986, P=0.054 > 0.05), while the dispersion degree of the change rate of F1 for /uai2/ is larger (/uai2/: SD 0.464, SEM 0.074; /ai/: SD 0.047, SEM 0.008). The change rate (1.283) of F2 for /uai2/ is significantly larger than that (0.854) of F2 for /ai/ (T=6.310, P=0.007 < 0.05), and the dispersion degree of the change rate of F2 for /uai2/ is also larger (/uai2/: SD 0.422, SEM 0.045; /ai/: SD 0.068, SEM 0.007).
4. Summary
For the transitional modes for triphthongs in Monguor language, this paper draws the conclusion that the change rates of the first parts for F1 or F2 are higher than those of the second parts; furthermore, the first parts for F1 or F2 are the transitional segments, and the second parts for F1 or F2 are stable segments. The analysis above shows that the preceding consonants have significant effect on the transitional modes of triphthongs from the perspective of change rates. The change rates of F2 for /iau1/, F1 for /uai1/, and F1 for /uai2/ are the same as those of the corresponding diphthongs. While the change rate of F1 for /iau1/ becomes significantly lower than that of the corresponding diphthong, the change rates of F2 for /iau2/, /uai1/, and /uai2/ become significantly larger than those of the corresponding diphthongs. The differences can also be observed from the figures of the formants of triphthongs in Monguor language.

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References
[1] Zhang H 2017a Coarticulatory Dispersion in NCV Sequences in Monguor Language MATEC Web of Conferences 125 pp 996-1001
[2] Zhang H 2017b Coarticulation of Nasal Vowels in Monguor Language Advances in Social Science Education and Humanities Research 107 pp 81-84
[3] Zhang H 2017c Acoustic Analysis of Nasal Vowels in Monguor Language Materials Science and Engineering 242 pp (012132)1-5
[4] Zhang H 2017d Acoustic Analysis of Monophthongs in Monguor Language Advances in Social Science Education and Humanities Research 146 pp 70-74
[5] Schatz T, Turnbull R, Bach F and Dupoux E 2017 A Quantitative Measure of the Impact of Coarticulation on Phone Discriminability INTERSPEECH pp 3033-3037
[6] Matthies M, Perrier P, Perkell J S and Zandipour M 2001 Variation in anticipatory coarticulation with changes in clarity and rate Journal of Speech Language & Hearing Research Jslhr 44(2) pp 340-353
[7] Whang J 2018 Recoverability-driven coarticulation: acoustic evidence from Japanese high vowel devoicing Journal of the Acoustical Society of America 143(2) pp 1159
[8] Chang S E, Ohde R N and Conture E G 2002 Coarticulation and formant transition rate in young children who stutter Journal of Speech Language & Hearing Research Jslhr 45(4) pp 676
[9] Wu Z and Lin M 2014 Tutorials on Experimental Phonetics Higher Education Press