The pattern of tongue positions and properties of Kazak vowels

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Abstract. Acoustic analysis of Kazak vowels has been undertaken and values of the first two formants are extracted as the data for the pattern of tongue positions. Both formant values and the pattern of tongue positions of Kazak vowels indicate that there is a relative minimal-pair contrast distribution among the vowels. Although all of the vowels are within the area of the cardinal vowels, most Kazak vowel are centralized and the ultimate of tongue positions is confined in a comparatively small area. Vowels [e] and [ɨ] are actually not that as the IPA signified.

1. Introduction
Research in Kazak phonetics has been greatly furthered in the past decade. Modern Kazak (Kazak version) written by Gong Shimin & Li Zengxiang and Modern Kazak (Kazak version) composed by the Language Committee of Xinjiang Province both make a complete description of Kazak phonetics including the biological and physical properties of the phonemes, the principles of phonetic harmony, the phenomena of phonetic changes in speech, so on and so forth; while Kazak Grammar compiled by the Institute of Linguistics of the Education and Science Department of the Republic of Kazakhstan offers the most detailed depiction of Kazak phonetics[1]. However, most of the research results are based on literature and documents. With the development of high-tech and advanced equipments in acoustic phonetics, biological phonetics and psychological phonetics, it is necessary and possible to set up a corpus of Kazak and work out scientific evidences and interpretations for all the phonetic phenomena, which will offer great help to the research of the evolution of the language, and promote the development of the language itself and its orthography in return.

In 2000, the Kazak Acoustic Parameter Corpus was completed in China[2], which drives a great leap in the research on Kazak acoustic phonetics, but detailed and systematic results are still not available. This paper starts from the model of the tongue positions of Kazak vowels to provide a perspective and visualized view on Kazak.

2. Research design
It has been demonstrated that there is a close relation between the tongue positions of vowels and the formant values. The first format (F1) is relevant to tongue height, while the second format (F2) is relevant to tongue region, and F2 is also relevant to lip-rounding[3]. Therefore, based on the data of F1 and F2, a pattern of tongue positions of vowels can be set.

2.1 Words for pronouncing
There are 9 vowels, 24 consonants, and 6 types of syllables in traditional Kazak: V, VC, VCC, CV, CVC, CVCC (V stands for vowel, and C stands for consonant), which can be formulized as (C)V(C(C)) (the bracket means the variable is optional). To avoid the influence of consonants to vowels and get comparably exact values of F1 and F2 of the vowels, vowel phonemes in Kazak phoneme list and one-syllable words of VC types were selected according to the Internet Kazak Corpus — Kazak-Chinese Dictionary uploaded by Li Jing[4] and Kazak-Chinese Dictionary compiled by Nurbek Abken[5]. The sample of the word list is as that in figure 1 and figure 2, and the IPA was given according to those in A Course of Acoustic Phonetics[6] and Modern Kazak Practical Grammar[7].

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Sample of vowels

**Figure 2.** Sample of VC-type word list

※ VN= vowel number, WN = word number, IPA=International Phonetic Alphabet, PhT=phonemic transcription, KZK=Kazak, ST=syllable type, WC=word class, CE=Chinese equivalent

### 2.2 Subjects

Kazaks believe there is no dialects in the language, because all Kazaks can communicate well, but in terms of phonetics Kazak is divided into north-east dialect and south-west dialect in China according to the population distribution and the tribes they used to belong to[8]. In this experiment, 3 males and 3 females were selected to pronounce the words. The subjects are at the age ranged from 18 to 30 — people at this age range speak typical popular Kazak. Among them, 2 males and 2 females are working as announcers at the Radio and Television Bureau of Kazak Autonomous County of Aksay Gansu Province, the other 1 male and 1 female are college students from Northwest Minzu University. All of them are Kazaks and can speak Kazak and Chinese fluently. 5 of the subjects are from Kazak Autonomous Prefecture of Yili Xinjiang Province, and 1 is from Kazak Autonomous County of Aksay Gansu Province, both of which are in the north-east Kazak dialect area.

### 2.3 Data collection

The phonetic signals were recorded at the studio with the software Audition 3.0 (Chinese version) and the equipments of a Lenovo laptop computer, an external sound card of Yamaha Steinberg UR22 with USB Audio Interface, and a Sony Omni directional microphone. Signals were collected at the sampling rate of 22050 Hz, 16-bit, single track and saved as Microsoft .wav file[9]. The sample of the phonetic signals is in figure 3.

The signals were then cut into separate and named according to the sequence of the subjects and the words. For example, M10001 is the file name of the sound of the first word pronounced by the first male, F10001 is the file name of the sound of the first word pronounced by the first female; M1V001 is the file name of the sound of the first vowel pronounced by the first male, F1V001 is the file name of the sound of the first vowel pronounced by the first female, so on and so forth. Praat was used for the analysis and formants collection as that in figure 4. The maximum formant was set at 5000Hz for the analysis of male signals, 5500Hz was set as the maximum formant for the analysis of female signals, and the number of formants was set at 5[10].
Figure 3. Sample of the phonetic signals

A comparably stable segment of the vowel was selected and the values of F1 and F2 were extracted by Praat as that in figure 4. The values—F1 of the vowel, F2 of the vowel, the onset time of the segment, the offset time of the segment, and the stable time—were put in Excel as that in figure 5, and the average values of the F1 and F2 of each vowel were got respectively as the data for tongue position analysis.

Figure 4. Wideband spectrum sample and sample of the stable segment of M20001 az (j)

Figure 5. Sample of formant values ※VF1=F1 of the vowel, VF2=F2 of the vowel, ONT=onset time, OFT=offset time, ST=stable time

3. Results analysis and findings

The formant data of males and females were averaged respectively, and graphs were drawn based on the data.

3.1 The cardinal vowels

Based on the action of human organs, the quality of a vowel can be determined by 3 or 4 items, which are tongue region, tongue height and lip-rounding[11]. Because of the limit of the mouth, the action area of the tongue is also limited. Research results have demonstrated the action area of the tongue is limited within the positions of four cardinal vowels [i],[u],[a] and [ɑ] as that in figure 6[12]. Within the quadrangle the tongue can act freely.

Figure 6. The limits of the tongue positions

Figure 7. The pattern of tongue positions of cardinal vowels published by IPA in 2005

In order to describe the tongue positions in the area, four values of close, close-mid, open-mid and open are set in longitude, and three values of front, central and back are set in altitude. Different vowels are applied on the 12 positions as the cardinal vowels as that in figure 7, which is the pattern of cardinal vowels’ tongue positions published by the International Phonetic Association (IPA) in 2005.
All the vowels from different languages in the world can be put into the area of the pattern (of course, there may be exceptions with further research on more and more languages).

3.2 Tongue positions and properties of Kazak vowels
The average values of F1 and F2 of males and females were extracted as that in table 1. Graphs were drawn based on the data.

3.2.1 The contrast distribution of Kazak vowels.
Data in table 1 indicate that vowel pairs of [ɑ]-[æ], [ɑ]-[e], [o]-[ø], [u]-[y] and, [ə]-[ɨ] are all greatly differentiated by tongue height. As data in table 2 show the difference values (D-value) of F1 of the pairs are all less than 100 Hz, while the difference values of F2 are more than 400Hz. This can be taken as an interpretation of Kazak vowels’ division into front vowels and back vowels, but Gong Shi-min also classified them into wide vowels and narrow vowels according to the opening of the mouth, as that in figure 8[13]. As is known, the opening of mouth is inversely proportional to tongue height, which is in proportion to the value of F1. The classification of Gong Shi-min can be demonstrated by data in table 2 as well, for all the D-values of [ɑ]-[ə], [æ]-[ɨ], [e]-[ɨ], [o]-[u] and [ø]-[y] are greater than zero (The bigger the value of F1, the wider the mouth open.). Therefore, the 9 vowels are actually in minimal-pair contrast distribution, that is [ɑ]-[æ], [ɑ]-[e], [ə]-[ɨ], [o]-[u], [ø]-[y], no matter from the term of tongue region or from the term of tongue height (mouth opening).

### Table 1. Formant values of males and females

| Vowels | MAF1a | MAF2a | FAF1b | FAF2b |
|--------|-------|-------|-------|-------|
| ɑ      | 732   | 1218  | 1030  | 1579  |
| æ      | 663   | 1711  | 963   | 2206  |
| e      | 428   | 1946  | 577   | 2321  |
| o      | 456   | 847   | 575   | 1044  |
| ø      | 401   | 1549  | 566   | 1994  |
| u      | 366   | 886   | 491   | 976   |
| y      | 339   | 1369  | 513   | 1814  |
| ə      | 485   | 1102  | 654   | 1313  |
| i      | 468   | 1629  | 617   | 2081  |

Table 2. D-values of vowel pairs

| unrounded vowels | D-value of MAF1 | D-value of MAF2 | D-value of FAF1 | D-value of FAF2 |
|------------------|----------------|----------------|----------------|----------------|
| [ɑ]-[æ]          | 69             | 493            | 67             | 627            |
| [ɑ]-[ɪ]          | 17             | 527            | 29             | 768            |
| [ɑ]-[e]          | 304            | 728            | 453            | 742            |
| [æ]-[e]          | 235            | 235            | 386            | 115            |
| [ɑ]-[ə]          | 247            | 116            | 376            | 267            |
| [æ]-[ɨ]          | 195            | 82             | 346            | 125            |
| [o]-[o]          | 55             | 702            | 9              | 950            |
| [ʊ]-[y]          | 27             | 483            | 22             | 838            |
| [o]-[u]          | 90             | 702            | 84             | 68             |
| [ø]-[y]          | 62             | 180            | 53             | 180            |
3.2.2 Tongue positions of Kazak vowels. Set F2 as the X-axis and F1 as the Y-axis, the pattern of tongue positions of Kazak vowels were designed based on the data in table 1 as that in figure 9 and figure 10.

![Figure 9. The pattern of male’s tongue positions](image)

![Figure 10. The pattern of female’s tongue positions](image)

Both of the two figures indicate apparently that [u][o][ʊ][ ø] are back vowels, [ɛ][æ][y][ø][ɨ] are front vowels. The division of the 9 vowels into front vowels and back vowels is actually based on a relative comparison, because [a] [y] [i] [ʊ] [ø] are comparatively central vowels in the pattern. Besides, [ɛ]:[æ]:[ɑ], [u]:[o]:[ø] are in apparent gradual opposition by tongue height.

Furthermore, vowel [ɨ] should deserve the attention. Compared with the pattern of cardinal vowels shown in Figure 7, all of Kazak vowels except [ɨ] are on the relative positions of the pattern. The tongue height of [ɨ] is between [æ] and [ɛ], and it is a front vowel instead of a central vowel as that in the pattern of cardinal vowels. Therefore, as Zheng Huan demonstrated “Kazak vowel [ɨ] is not the vowel [i] (front high vowel), [i] (central high vowel) or [γ] (back semi-high vowel), instead [ɛ] is a better sign for the phoneme”[14].

The vowel [ɛ] is special, because in old Turkic, there are only 8 vowels as that in table 3[15], and in the evolution of the language, the vowel [i] (Here [i] equals to [ɨ] in the above.) in some old Turkic words evolutes into [ɛ] in Kazak[16]. The formant values and the tongue position pattern also indicate [ɛ] is a front high vowel.

| IPA  | Old Turkic | Kazak  |
|------|------------|--------|
| a    | a          | 1      |
| æ    | å          | ɨ      |
| y    | Ü          | ú      |
| ø    | Ö          | ſ      |
| u    | u          | ʊ      |
| o    | o          | ɿ      |
| ə    | ɨ          | ɨ      |
| i    | i          | ɨ      |

![Table 3. Comparison of vowels in old Turkic and Kazak](image)

![Figure 11. The sample of wideband](image)
In spoken Kazak, if [e] is the first letter of a word, an [j] is often added before [e][17]. The wideband spectrum of [e] of the subjects shows an obvious sliding process as that in figure 11, but whether the sound is a single vowel [e] or a diphthong [ie], more research and evidences are needed.

4. Conclusion
Both formant values and the pattern of tongue positions of Kazak vowels indicate that there is a relatively minimal-pair contract distribution among the vowels. Although all of the vowels are within the area of the cardinal vowels, most Kazak vowel are centralized and the ultimate of tongue positions is confined in a comparatively small area. Vowels [e] and [i] are actually not that as the IPA signified. More researches on the properties and the IPA signs of the two vowels are required.

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