A Comparative Analysis of Acoustic Characteristics between Kazak & Uyghur Mandarin Learners and Standard Mandarin Speakers

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Abstract —**In this paper, based on the vowel and phonological pronunciation corpora of 20 Kazakh undergraduate Mandarin learners, 10 Uyghur learners, and 10 standard pronunciations, under the framework of the phonetic learning model and comparative analysis, the method of experimental phonetics will be applied to the Kazak and Uyghur learners. The learners and standard speaker Mandarin vowels were analyzed for acoustic characteristics, such as formant frequency values, the vowel duration similarity and other prosodic parameters were compared with the standard speaker. These results are conducive to providing learners with effective teaching-related reference information, providing reliable and correct parameters and pronunciation assessments for computer-assisted language teaching systems (CALLs), as well as improving the accuracy of multinational Chinese Putonghua speech recognition and ethnic identification.**

Keywords-Mandarin monophthongs，Uyghur，Kazakh learners，Acoustic features; comparative experiment，Ethnic identification

I. INTRODUCTION

With the social progress and economic development, the communication field of human beings has also expanded rapidly. In the process of communication, the ability of speaking standard and fluent Mandarin has become an important criterion for measuring conversational ability. At present, Mandarin (Putonghua) has been promoted very comprehensively in China and is now developed to a new stage [1] [2]. At the same time, in the past few years, Mandarin (Putonghua) has become a tool for information exchange between ethnic minorities in daily communication and also in the field of intelligent information processing systems.

Mandarin Chinese (MC), as a lingua franca for Chinese people, has received considerable attention in previous studies by scholars with varied academic backgrounds. Yet, comparatively few studies have been carried out on the influence of one's dialect on the production of MC, which learners acquired as a "second language", especially in the case of the MC produced by minority groups, for example, Kazakh、Uyghur speakers. Such impact is most evident in the production of target vowels of MC, which is also the most difficult to eliminate. It thus makes Chinese speech processing difficult when it comes to "accented" MC, especially in the building of automatic speech recognition system. For that reason, this paper will carry out an experimental study on the features of MC monophthongs by Kazakh and Uyghur speakers.

As known to all, for the Mandarin learners, the pronunciation of Mandarin will be interfered by their native accent, which will cause some deviation between the Mandarin learners and the native Mandarin speakers. Therefore, the acoustic character of the Mandarin learners other than the standard Mandarin speech recognition system, which will reduce the recognition rate, is used to recognize between the Mandarin learners and the native Mandarin speakers. Many scholars have been engaged in research in this field, and have made many academic achievements. For example, a bilingual comparative experiment was conducted on the acquisition of Tibetan Mandarin learners whose mother tongue is not Mandarin [3]. So far, there have been many researches on the learning of Mandarin by Kazakh and Uyghur students in the academic circles [4][5], but there is few research on the acoustic characteristics of Mandarin learning in Kazakh and Uyghur learners.

For most students from minority regions, L1 is the native language (Kazakh and Uyghur Language for example), with Chinese as L2 and English as L3. Given the differences and similarities among the three languages in their vowel systems, such a learning process may lead to the phonetic transfer of L1 and L2 on L3 in the process of L3 vowel learning. So the present research can help strengthen phonetic teaching among ethnic minorities and provide more effective empirical data for speech synthesis and speech recognition of ethnic minorities' [6-8].

Contrastive Analysis Hypothesis (CAH) [9] and Speech Learning Model (SLM) [10] are closely related to the studies of second language (L2) acquisition. CAH claims that the principal barrier to L2 acquisition is the interference of the first language (L1) system with the L2 system. It predicts that L2 phonemes that are similar to L1 phonemes will be "easy", while L2 phonemes that are different from those in L1 will be "hard". Flege [11] obtained evidence against CAH, i.e., the "new" doesn't mean the "difficult", while the "similar" doesn't mean the "easy". "A new phonetic category can be established for an L2 sound that differs phonetically from the closest L1 sound if bilinguals discern at least some of the phonetic difference between the L1 and L2"[9]. It predicts that successful L2 production relies on the construction of new phonetic categories for the constituents in L2 which do not have any counterparts in L1. So far, various experiments have been conducted under the framework of SLM, such as Wang & Deng [12] and Wang & Li [13]. However, comparatively few studies have been carried out on the influence of Kazakh and Uyghur speakers' mother tongue on their production of MC monophthongs. This paper is thus to examine such influence in the case of Kazakh and Uyghur speakers through an acoustic experiment.

This paper focuses on the acoustic characteristics of the pronunciation of Mandarin vowels of the Kazakh and Uyghur Mandarin learners and native Mandarin speakers. Based on the method of acoustic features, the vowel pronunciation experiment of Mandarin learners is used to compare the acoustic characteristics of the vowels of Uyghur and Kazakh Mandarin learners through quantitative experimental research methods. The purpose of this research is as follows: it is beneficial to provide learners with effective reference information related to teaching, provide reliable and correct parameters and pronunciation evaluation for computer-aided language teaching system (CALL), and also improve multi-ethnic Mandarin speech recognition accuracy.

II. Experimental Designs

A. Subjects

This paper studies the acoustic characteristics of the pronunciation of Mandarin vowels of the Kazakh and Uyghur Mandarin ethnic learners, that is, the acoustic characteristics of the native Kazakh speakers and native Uyghur speakers in the process of learning Mandarin. Therefore, the learners' Chinese minority Chinese proficiency test (MHK) oral scores are used as the basis. In the specified range, 15 Kazakh students (7 males and 8 females) and 10 Uyghur students (5 males and 5 males) from Xinjiang University, aged 20-26 were selected as subjects. They started learning Mandarin from the third grade of elementary school and their Chinese proficiency was MHK Level 4. Their Mandarin teachers were from the same nationality (either Kazakh or Uyghur) and have passed the MHK test. And also the Mandarin level of these students' parents was poor. The everyday communication between the students and their parents is mainly carried out in their national language (either Kazakh or Uyghur) and there is no obvious hearing impairment of these students and the articulation is clear. The other group is made of 10 students in Han nationality and comes from Beijing. They are native Mandarin speakers and their average age is 24 years old.

B. Stimuli and Procedure

The voice information required for the experiment is collected in a dedicated recording studio, and the hardware devices used include a notebook, an external sound card, a microphone, and some interconnected data lines. The external sound card can achieve functions such as adjusting the volume of sound, reducing noise, and monitoring the popping sound. The acquisition software is a recording project written in the Matlab environment. The reading data of each subject was 50 Chinese single bytes, and the acquisition frequency was 16 kHz. After collecting the voices of the participants, the collected Kazakh Mandarin learners' data and the native Mandarin speakers' voices are marked. In this study, manual audio proofreading was performed on 35 people's voices, which achieved at a high accuracy. Based on the labeled monosyllabic notes, the Praat speech software can be used to generate a three-dimensional map of the sound samples and extract the formant acoustic parameters.

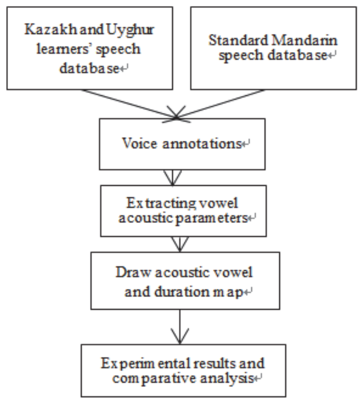

Figure 1. Experimental Flow Chart

III. Experimental results and analysis

C. Formant analysis

The unit sound refers to a vowel whose tongue position, lip shape, and opening degree are always unchanged during the pronunciation. One of the important quality signs of vowels is the vowel formant, which resonates through the excitation source as a vibration. Different vowels have different acoustic cavity shapes, and thus have their respective formants [14]. From the study of acoustic characteristics, we can learn that the learner's pronunciation vowel has a certain influence on the F1 and F2 values. When the learner pronounces the vowel, the F1 frequency value is inversely proportional to the height of the tongue. It can also be said that when the learner pronounces vowel the higher the tongue position, the lower the first formant, the lower the tongue position, the higher the first resonance peak; when the learner pronounces, the tongue position is proportional to the F2 frequency value, that is, the learner's tongue is on the front. The higher the second resonance peak, the lower the tongue position, and the lower the F2 frequency value [15].

In order to objectively and accurately study the acoustic characteristics of the learner's Mandarin phonetic output, here we extract the F1 and F2 of all the tested speeches in order to compare and analyze the formant frequency values, and extract all the resonances peak data [16] in the vowel relative segment. Since the speech has significant individual characteristics, that is, in order to eliminate the individual differences of different speakers, the formant is used to calculate the formant data. But in this situation, the data of each phonetic sample cannot be obtained, that is, the characteristics of the sound are not truly reflected. Therefore, the sound pattern theory of Shifeng is adopted in this study. F2 to F5 is normalized, and we further calculate the average value of each resonance peak of each group, and convert it into Bark value [17]. We will further normalize the Bark values, formulas (1) and (2), as follows:

$$Bark = 7 * \ln\left\{ (f/650) + \left[(f/650)^2 + 1 \right]^{\frac{1}{2}} \right\} \quad (1)$$

$$V = \frac{B_{x} - B_{\min}}{B_{\max} - B_{\min}} \times 100 \quad (2)$$

D. Acoustic analysis

The data of the first formant (F1) and the second formant (F2) of the vowel determine the sound quality of the vowel. After extracting the formant frequency of the vowel and converting it to the Barker value and normalizing it, an acoustic vowel map can be drawn. The acoustic vowel map is a visualization of the resonance characteristics of the entire acoustic cavity, which is much more accurate than the conventional tongue map. We used one-way analysis of variance to analyze the significant differences in pronunciation between Kazakh and Uyghur Mandarin learners and the native Mandarin speakers. Figures 1shows the difference of acoustic vowels pronunciation of Kazakh female Mandarin learners and the native female Mandarin speakers, Figures 2 shows the difference of acoustic vowels pronunciation of Uyghur female Mandarin learners and the native female Mandarin speakers, Figures 3 and 4 are the difference between Kazakh male Mandarin learners and the native male Mandarin speakers in acoustic vowels pronunciation, respectively,

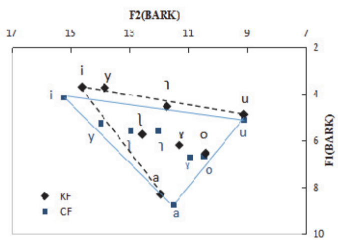

Figure 2. Kazakh learners' acoustic vowel map

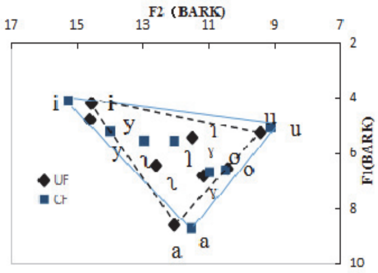

Figure 3. Uyghur learners' acoustic vowel map

Figure 2 shows that Kazakh female Mandarin learners and native female Mandarin speakers have systematic differences in unit sound output. Through the results of one-way analysis of variance, it is concluded that the tongue position of the two groups is significantly different. Except for /ʅ/, the F1 of the Kazakh female learner's Mandarin phone is smaller than the native speakers'. In addition to /a, γ / F2 of the unit sound, others are smaller than the native speakers of Mandarin. In terms of /i, y, ɿ /, the average of F1 and F2 of Kazakh female learners is higher than that of native Mandarin speakers. The average values of F1 and F2 are slightly lower, and it can be inferred that the tongue position of the Minority Mandarin (Kazak & Uyghur) learner when pronouncing the vowels is higher. And the vowel /i/ ($pF1<0.05$, $pF2<0.05$) is the most different from that of the native speakers'. Secondly, the difference between vowels /y, ɿ /($pF1<0.05$, $pF2>0.05$) is significant in F1. The main difference between Kazakh Mandarin learners and the native Mandarin speakers is the high and low tongue position. The second formant data does not reflect the difference of specific statistical significance ($pF2>0.05$). In terms of vowels/a/ and /γ/, the average value of F1 of Kazakh female learners is lower than that of the native Mandarin speakers, and the F2 frequency value of the output is higher than that of the native Mandarin speakers. What's more, vowel /a/(The $pFe1<0.05$, $pF2<0.01$) yielded a higher tongue position, which was more significant than that of the native speakers. However, the difference in output of vowels/γ/($pF1<0.01$, $pF2>0.05$) is extremely significant. The output tongue of Kazakh female learners is significantly higher, while the difference of vowel/γ/($pF2>0.05$) is not significant. . The results of the analysis of variance show that for vowels/ʅ, o, u/, the frequency values of the Kazakh learners and the native Mandarin speakers are ʅ, o, u/($pF1>0.05$, $pF2>0.05$). There is no significant difference on F1 or F2.

Figure 3 show that female Uyghur Mandarin-learners and native Mandarin speakers have systematic differences in unit sound output. Through the results of one-way analysis of variance, it is concluded that the tongue position of the two groups is significantly different. The F1 of the Uyghur female learners' vowel pronunciation of /a，γ，ʅ，i/ is larger than the native Mandarin speakers, while the F2 of the Uyghur female learners' unit sounds /a, γ, u, y/ is larger than the native speakers'. According to the analysis of variance, the difference between Uyghur female learners' pronunciation of vowels like /i,o/ (pF1<0.01,pF2<0.01) and native Mandarin speakers' is very obvious. The speaker's tongue of vowel /i/ is higher and the speaker's tongue position of vowel /o/ is lower and more backwards, the speaker's tongue position of vowel /ʅ/ (pF1<0.05, pF2<0.05) is lower and more backwards, too. Secondly, the difference between vowels /a, e/ (pF1<0.01, pF2>0.05) and /u/(pF1<0.05, pF2>0.05) is significant in F1. The main difference between Uyghur female Mandarin learners and native Mandarin speakers is at the position of front and back point of the tongue. The two formant data did not reflect the difference in specific statistical significance (pF2>0.05). When the learner issued /a, u/ vowel, the tongue position was in front, and when issued /e/, the tongue position was backwards, vowel /ɿ/ (pF1>0.05, pF2<0.05) as long as the difference is in F2, the tongue position is basically the same, and the tongue position is posterior. The vowel /ʅ/ analysis showed that for the vowel /y/ (pF1>0.05, pF2>0.05), the frequency value of the output had no significant difference on F1 and F2.

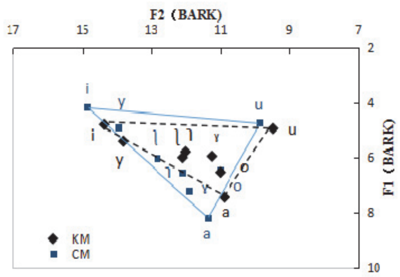

Figure 4. Kazakh learners' acoustic vowel map

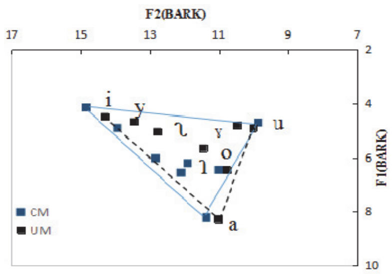

Figure 5. Uyghur learners' acoustic vowel map

As can be seen in Figure 4, when Kazakh male Mandarin learners produce unit sounds /i, y, o, u/, the F1 is higher than the native Mandarin speakers, and the F2 value of the vowel produced by Kazakh male Mandarin learners is lower than the native Mandarin speakers. As a result, the Kazakh learners' output is low. The analysis of variance showed that the output difference of vowel /i/ (pF2<0.01) and vowel/u/ (pF2<0.05) was more significant. The Kazakh learners' tongue position was significantly lower and the F2 value did not reflect the statistically significant difference (pF2>0.05). In addition, for vowels /y,o/ (pF1>0.05, pF2>0.05), there is no significant difference between Kazakh learners and the native Mandarin speakers. The F1 of the Kazakh male Mandarin learners' voices of /s, γ, a, ɿ, ʅ/ are smaller than the native Mandarin speakers, except for F2 of /ʅ/, other Kazakh learners' are smaller than native speakers'. There is a discernible difference between the two groups of subjects. It can be seen that the learner's vowel output has a higher tongue position, especially in vowel/γ / (pF1<0.05, pF2<0.05). The difference is the most obvious. Kazakh male Mandarin learners' voices mainly distinguish vowels /a/ (pF1<0.05, pF2>0.05) with linguistic height, and for vowels/ɿ/(pF1<0.01, pF2>0.05 the difference is mainly reflected in the height of the tongue. We can know from the analysis of variance that the difference between the F1 and F2 values of the vowel /ʅ/ output of the learner and the native speaker is not significant (pF1>0.05, pF2>0.05).

We can see from Figure 5 that for Uyghur male learners, except for vowels /a, γ, i, u/, the F1 value of the Uyghur male learners' Mandarin phone is smaller than the native Mandarin speakers'. The F2 value of the unit sound of Uyghur male learner is smaller than that of the native speakers. The F1 and F2 value of the above two groups are analyzed by one-way ANOVA, and the vowels /a, γ, i, ɿ/ are known. The difference between /y/ (pF1<0.01, pF2<0.01) is extremely significant. The tongue position of the learner's of vowel /a, γ, i, y/ is significantly lower than the front, and /ɿ/ tongue is higher. There was a difference in the tongue position of vowel /ʅ/ (pF1<0.05, pF2<0.01), which was higher than the front. The main difference of vowel /o, u/ (pF1>0.05, pF2<0.01) is that the tongue position is higher or lower while the tongue position remained unchanged. The second formant data does not reflect the difference of specific statistical significance. The vowel/o/ (pF1>0.05, pF2<0.01) differed from the native speakers in that the tongue position was higher. In the case of /u/, the tongue is lower.

The vowel pronunciation of the minority (Kazak & Uyghur) learners and the native Mandarin speakers is analyzed by variance. In order to compare the pronunciation difference between the learners and the native speakers, the Euclidean distance is used to calculate the distance between the learners and the native speakers in the acoustic vowel. The formula is:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad (3)$$

Where （x_1, y_1）, (x_2, y_2) are the two points in the acoustic vowel diagram, the Bark value of F2 is x, and the Bark value of F1 is y. The table below shows the unit distance of minority (Kazak & Uyghur) learners and the native Mandarin speakers.

TABLE I. LEARNER AND STANDARD SPEAKER VOWEL EUCLIDEAN DISTANCE

Vowel	a	o	γ	ɿ	ʅ	i	u	y
Male KM-CM	0.91	0.48	1.05	1.42	0.09	0.81	0.46	0.51
Male UM-CM	0.34	0.21	1.11	2.01	0.99	0.63	0.24	0.54
Female KF- CF	0.60	0.12	0.61	1.08	0.42	0.77	0.20	1.51
Female UF- CF	0.88	0.084	0.73	0.55	0.94	0.7	0.37	0.75

In Table 1, according to the Euclidean distance between the acoustic vowel diagrams, the EDKM-CM of the vowels /ʅ, o, u/ are: 0.09, 0.46, 0.48, respectively, indicating that the male learners pronounced /ʅ, o, u/ is of the best. And the EDKM-CM of vowel /y, i, a/ is 0.51, 0.81, 0.91, respectively. So it is more difficult to make these sounds for the learners, which means it is difficult for the learners to pronounce vowel/ɿ, γ/. For female learners, the EDKM-CM of vowels /o,u,ʅ/ are: 0.12, 0.20, 0.42, indicating female learners pronounced /o,u,ʅ/ at the best. While the EDKM-CM value of vowel /a,γ,i/ is 0.60, 0.61, and 0.77. So it is more difficult to make these sounds. The learners have difficulty in the pronunciation of vowels /ɿ, y/.

E. The Similarity Comparison of Vowel Duration

We need to further analyze the difference of vowel duration between the native Mandarin speakers and minority (Kazak & Uyghur) Mandarin learners. In this process, we introduce the concept of Unit Sound Duration Similarity. The Pearson correlation coefficient in equation (3.3) below will provide objective data to show the similarity of the vowel duration of minority (Kazak & Uyghur) Mandarin learners and the native Mandarin speakers. Correlation coefficient is a commonly used index to check whether the consistency of two sets of data sequences is good [18]. Therefore, it can be used to measure the acoustic consistency between minority (Kazak & Uyghur) Mandarin learners and the native Mandarin speakers. Hypothesis $X=\{x_1,x_2,...,x_n\}$ and $Y=\{y_1,y_2,...,y_n\}$ are the speech sequences of two different speakers of the same pronunciation sample sequence, respectively, n stands for the number of samples, then their correlation coefficients are calculated as follows:

$$P_{X,Y} = \frac{\sum (X-\overline{X})(Y-\overline{Y})}{\left(\sqrt{\sum_{i=1}^{n}(X_i-\overline{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i-\overline{Y})^2}\right)} \tag{4}$$

Where, X_i, Y_i and $i \in (1,8)$ are the corresponding eight-unit time distribution vectors, $P_{X,Y} \in (-1,1)$ means that when the linear relationship between the two variables X and Y is very high, the correlation coefficient is either 1 or -1; the correlation coefficient is less than 0; if the correlation coefficient is equal to 0 , it means that the similarity between X and Y is very low and the difference is high. Table 2 below compares the similarity of vowel duration distribution between minority (Kazak & Uyghur) Mandarin learners and the native Mandarin speakers.

TABLE II. DISTRIBUTION SIMILARITY OF VOWEL DURATION

Vowel	a	o	γ	ɿ	ʅ	i	u	y
Male KM-CM	0.50	0.82	0.45	0.44	0.66	0.56	0.54	0.48
Male UM-CM	0.54	0.66	0.52	0.39	0.61	0.48	0.53	0.56
female KF- CF	0.76	0.68	0.62	0.64	0.58	0.54	058	0.44
Female UF- CF	0.52	0.45	0.55	0.72	0.65	0.38	0.55	0.50

In Table 2, the distribution of the duration distribution is calculated based on the distribution of the length of the native mandarin (5 male, 5 female) speakers. As can be seen from Table :

- the similarity of time length of vowel /o/ of Kazakh male Mandarin speakers is very strong, and also their correlation degree of vowel duration /ʅ/ is strong. The duration similarity of vowel /a、γ、ɿ、i、u、y/ when compared with the native male Mandarin speakers is 0.50, 0.45, 0.44, 0.56, 0.54, and 0.48, respectively. The correlation degree of vowels between Kazakh male Mandarin learners and the native male speakers is similar, indicating that the vowel pronunciation is slightly different.
- The duration similarity of Kazakh female Mandarin learners' vowel pronunciation of /a, o, γ, ɿ/, when compared with that of the native female Mandarin speakers, is 0.76, 0.68, 0.62, 0.64, respectively. We can see that the duration correlation with the native female speakers' is very strong. And duration similarity of vowel /ʅ, i, u, y/ when compared with the native female speakers' are 0.58, 0.54, 0.58, and 0.44, respectively, indicating that the temperament correlations of the two groups of speakers are moderate.
- According to the similarity analysis between the Uyghur learners and the native learners, the duration of the vowels /o, ʅ/ of the Uyghur male speakers is 0.66, 0.61, respectively. The vowel /ɿ, ʅ/ duration similarity of female Uyghur Mandarin-learners' is 0.72 and 0.65, respectively, which is strongly correlated with that of the native female speakers.
- While the duration of the vowel /a,o,γ,u,y/ when compared with the native female speakers', the value is 0.52, 0.45, 0.55, 0.55, and 0.50, respectively, indicating that the vowel duration of the two groups of speakers is moderate. The duration of vowel /i/ is 0.38, which is lower than the similarity of other vowel durations. It can be seen that the vowel duration of the female Uyghur Mandarin-learners is similar to that of

the native female speakers, indicating that the length of the vowel pronunciation is different.

IV. Conclusions

In this paper, 10 Uyghur Mandarin learners and 20 Kazakh Mandarin learners are taken as research object. The purpose of the contrast experiment is to provide effective reference information for the learners, and to provide a reference for the development of natural language speech synthesis and high-precision speech recognition technology for minority Mandarin learners, and to provide reliable computer-aided speech systems with a much more correct parameters and pronunciation assessment.

In this study, the experimental acoustics method was used to compare the acoustic characteristics of the Uyghur and Kazakh Mandarin learners. By comparing the experimental results：

- the Mandarin syllables of the Uyghur male learners/ a, u / pronunciation is the best, and they have problems with the pronunciation of vowels / ɿ, ʅ, i, y /.
- As for Uyghur female Mandarin learners, the vowel / u, ɿ / pronunciation are the best. They have pronunciation difficulty in vowels /o, ɣ, i/. The best acoustic vowel performance for Kazakh male learners are /o, y/, and they have difficulty in vowels / ɣ, ɿ /, while female learners pronounce /o, u, ʅ / the best, but also have difficulty in pronunciation of vowel /a, i/.
- In general, Uyghur learners pronounce vowels /u/ the best, while Kazakh learners pronounce vowel /o/ the best. For the duration of the vowel unit, the length of the vowels of the Uyghur learners is longer than that of the native Mandarin speakers, while the length of the Kazakh learners is always different to collect for analysis.

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