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ACOUSTIC CHARACTERISTICS OF CHINESE FIRST-LEVEL VOWELS PRODUCTION BY KAZAKH LEARNERS

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Abstract

Kazakhstan, a Central Asian country, boasts a rich and diverse linguistic landscape, with Kazakh as its official language. The objective of this study was to analyze the acoustic characteristics of seven Chinese first-level vowels produced by Kazakh learners. Fourteen Kazakh learners of Mandarin Chinese were recruited, and the acoustic data obtained from these participants were meticulously compared. Each participant was recorded while producing the seven Chinese vowels, with each utterance being repeated nine times to ensure consistency and reliability. This rigorous approach aimed to minimize variability and ensure the accuracy of the findings. The acoustic data were then analyzed using Mini-Speech Lab software, focusing on extracting the formant frequencies (F1 and F2) of the seven vowels. The analysis revealed that Kazakh learners encountered significant challenges in producing apical vowels, while they exhibited no difficulty in articulating high vowels. The linguistic background of Kazakhstan, where both Kazakh and Russian phonetic systems differ significantly from Mandarin, might contribute to the specific challenges faced by Kazakh learners in mastering Mandarin vowels. The study offers important implications for the development of effective instructional strategies aimed at improving vowel production in Kazakh learners of Chinese, thereby enhancing their overall language acquisition process.

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Keywords: Acoustic characteristics; first-level vowel production; Kazakh speakers; L2 speakers of Chinese; Mandarin Chinese

Abstrak

Kazakhstan, sebuah negara di Asia Tengah, memiliki landskap linguistik yang kaya dan beragam, dengan bahasa Kazakh sebagai bahasa rasminya. Objektif kajian ini adalah untuk menganalisis ciri-ciri akustik bagi tujuh vokal peringkat pertama bahasa Cina yang dihasilkan oleh pelajar Kazakh. Sebanyak empat belas pelajar Kazakh yang mempelajari bahasa Mandarin telah direkrut, dan data akustik yang diperoleh daripada peserta ini dibandingkan dengan teliti. Setiap peserta direkodkan semasa menghasilkan tujuh vokal bahasa Cina, dengan setiap sebutan diulang sembilan kali untuk memastikan konsistensi dan kebolehpercayaan. Pendekatan yang ketat ini bertujuan untuk mengurangkan variasi dan memastikan ketepatan penemuan. Data akustik tersebut kemudian dianalisis menggunakan perisian Mini-Speech Lab, dengan penekanan pada pengekstrakan frekuensi formant (F1 dan F2) bagi tujuh vokal tersebut. Analisis menunjukkan bahawa pelajar Kazakh menghadapi cabaran yang ketara dalam menghasilkan vokal apikal, manakala mereka tidak mengalami kesukaran dalam mengartikulasikan vokal tinggi. Latar belakang linguistik Kazakhstan, di mana kedua-dua sistem fonetik Kazakh dan Rusia sangat berbeza daripada bahasa Mandarin, mungkin menyumbang kepada cabaran tertentu yang dihadapi oleh pelajar Kazakh dalam menguasai vokal Mandarin. Kajian ini menawarkan implikasi penting untuk pembangunan strategi pengajaran yang berkesan yang bertujuan meningkatkan penghasilan vokal dalam kalangan pelajar Kazakh bahasa Cina, sekali gus memperkukuh proses pemerolehan bahasa mereka secara keseluruhan.

KataKunci: Bahasa Mandarin; ciri-ciri akustik; penghasilan vokal tahap pertama; penutur Kazakh; penutur L2 bahasa Cina

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1.0 INTRODUCTION

Chinese is a vowel-dominated language. The first-level vowel, also called the cardinal vowel, is the most basic phoneme in Chinese vowels. It has been proposed that there are seven single vowels in Chinese Mandarin, i.e., [A, i, u, ɿ, ʅ, y, ɤ, ɛ, ɚ, o] (Wang, 1999; Shi, 2002). Better pronunciation of first-level vowels is a prerequisite for learning other compound vowels. Therefore, in teaching Chinese as a second language (L2), we should pay special attention to vowels in order to lay a solid foundation for learners' further advancement (Yu, 1995).

Most of the literature on pronunciation error analysis of Chinese vowel production by Kazakh learners is written in Chinese. Li (2007) comprehensively analyzed Chinese vowel errors by Kazakh speakers, focusing mainly on an impressionistic analysis. Li (2007) identified Chinese vowel errors made by nine Kazakh speakers, showing that learners cannot distinguish [i] from [ɿ] and [ʅ] in various contexts. In addition, [y] and [ɚ] are also challenging for learners to acquire. More recent studies of Chinese vowel error patterns by Kazakh speakers are also based on impressionistic description, such as Li (2007), He (2009), Ganati (2013), Jia (2014), Gao (2017), Wu (2018), and Rakhymbayeva (2019). Based on these impressionistic descriptions, common production patterns of Chinese vowels by Kazakh speakers can be summarized: (1) the dorsal vowel [ɤ] is pronounced as retroflex [ər]; (2) the rounded vowel [o] is replaced by the unrounded vowel [ɤ]; (3) the high rounded vowel [y] is often pronounced as a compound vowel [iou]; (4) [ɿ] and [ʅ] are difficult to distinguish between [si] and [tʂi].

Following advancements in technology, acoustic measurement can be widely applied to linguistic research, including second language acquisition studies. Compared with the previously used method of impressionistic description, acoustic analysis can provide a more objective and accurate diagnosis of speech production deviations by L2 speakers. Ma (2019) analyzed the pronunciation errors of zh [tʂ], ch

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[tʂʰ], sh [ʂ], and r[ʐ] among Kazakh students by employing Praat software. Arkin and Wu (2024) compared the formant frequencies, acoustic vowel plots, and vowel duration parameters of intermediate-level Mandarin learners with those of standard Mandarin speakers. A study was conducted to investigate the pronunciation of Mandarin non-low vowels, particularly /y/, by three Korean speakers learning Chinese as a second language and three Chinese native speakers, highlighting areas of pronunciation confusion (Duan, 2024). Yu and Arkin (2022) recruited 30 Chinese learners and 10 Chinese native speakers to investigate the pronunciation difficulties of Chinese diphthongs. Other studies mainly focused on the pronunciation of Chinese tone, rhotic onset/ɹ/, dental obstruent, plosives and affricates and tone production (Dassanayake, 2023; Liu & Chen, 2021; Hansen, Chen & Bell, 2020; Wang & Jia, 2022; Wang & Chen, 2020; Zhang & Liu, 2020). However, despite extensive research on double vowels, tone, consonants pronunciation in Chines as a second language (L2) acquisition, there remains a lack of focus regarding the pronunciation of Mandarin first-level vowels by Kazakhstan L2 Chinese speakers, which this study aims to address. Its findings can help identify the Chinese first-level vowel production problems of Kazakh-speaking students and thus improve the teaching and learning of L2 Chinese.

2.0 MATERIALS AND METHODS

2.1 Stimuli

When selecting Chinese characters for use in this study, the words should be simple, straightforward, and easy for students to recognize. In the selection process, syllables with unaspirated stop initials are preferred because stops produce a clear vertical stripe, known as a burst bar, in spectrograms, making them easier to analyze in this study. Following this, syllables with zero initials are selected. For certain syllables such as [ɿ] and [ʅ], which have syllable limitations, unaspirated affricates are preferred, with aspirated affricates as a backup option. Syllables containing fricatives,

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nasals, and laterals are not chosen as target words. The target words are designed from Wen (2008).

The word list was comprised of seven targeted words presented in Chinese characters, as listed in Table 1. Participants were recorded reading out loud the Chinese characters in the word list (details are described in Section 2.2 below), to provide data for further analysis.

Table 1. Word list of Chinese first-level vowels

vowel	[i]	[y]	[u]	[A]	[ə]	[ɿ]	[ʅ]
word	衣	鱼	屋	阿	哥	资	知

2.2 Participants, Procedures, and Recording Settings

Fourteen Kazakh-speaking learners of L2 Chinese took part in the study. They were university students studying at a university in China. The 14 Kazakh students (seven males and seven females) were aged 19 to 21 at the time of the study. They were all elementary Chinese learners, and their mother tongue was Kazakh. The age difference factor was not considered in the study, and we expect to examine it in a future study. All the male participants are marked as M and females as W. For the participants, no language, psychiatric, or psychological disorders were reported.

The study was conducted individually in a quiet room at the participants' university. The participants were asked to read the items from the word list out loud clearly at their regular speech rate, and each item was repeated nine times (Shi, 2008; Gu, 2012). They were allowed to self-correct their production if they realized that they had read an item incorrectly. The participants sat quietly to one side, recording the participants' pronunciation, but did not divulge to the participants whether their pronunciation was correct.

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The KX-3 sound card is a professional-grade external audio interface that offers high-resolution sound processing. Adobe Audition is a powerful digital audio workstation (DAW) widely used in professional audio production. The Saramonic SR-MV 2000 is a high-performance microphone designed to capture clear and detailed audio. Audio recordings were made using a KX-3 independent external sound card, Adobe Audition 3.0, and a Saramonic SR-MV 2000 microphone to ensure high-quality audio capture and precise editing capabilities. The use of professional-grade equipment was essential to achieve clear, uncompressed audio, which is critical for the integrity of the recorded data. The recording was set to mono channel; the sampling rate was 44,100 Hz with 16-bit resolution, and the recordings were saved in Wav. Format (Wang, 2022).

2.3 Sampling Method

Purposive or judgmental sampling is one of the non-probability sampling techniques in which particular settings persons or events are selected deliberately to provide important information that cannot be obtained from other choices (Maxwell, 2013). It is deployed, as the focus of the research is on Kazakh Chinese beginners.

2.4 Acoustic Measurement of Formant

Shi (2002) and Shi, Ran and Wang (2010) proposed that the main measurement parameters for the acoustic analysis of vowels are the values of the first formant (F1) and the second formant (F2).

Mini-speech Lab software developed by Nankai University (China) was used to measure the formants by mapping each vowel chart (Gu, 2012; Kang, 2014). After completing the vowel chart, we clicked the sub-command “Save current vowel map” in the “Vowel map” command. Then we clicked “Show saved vowel map data,” and the data of each vowel were displayed. After that, the data were copied into an Excel table. Here we selected nine formants for each vowel from a particular speaker to

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ensure higher accuracy of the formant frequency measurements. As an example, consider the extraction of formants for the vowel [A] produced by M1 (the first male speaker). Nine formants were chosen to calculate the average formant value (F1 and F2) of [A]. Using a larger number of formants allows for a more detailed and comprehensive analysis of the acoustic properties of the vowel. This ensures that the subtleties in the vowel's sound quality are captured, which might be missed if only the primary formants were considered. Averaging across nine formants can make the resulting data more robust and reliable by minimizing the impact of any anomalies or variations that might occur if fewer formants were used. This leads to a more accurate representation of the vowel's formant structure. For M1, 63 samples (9 formants × 7 vowels) were acquired. Based on this measurement, 882 samples (14 speakers × 9 formants × 7 vowels) were obtained.

3.0 RESULTS AND DISCUSSION

3.1. Formant Values

Table 2 shows the formant values of Chinese first-level vowels produced by the 14 L2 speakers from Kazakhstan.

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Table 2. Formant values of first-level vowels in Mandarin Chinese

	A		ɤ		i		u		y		ʅ		ɿ	
	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
M1	701	1095.8	497.7	1079.1	294.3	1966.7	323	668	311	1976.3	387.6	1265.7	449.8	1091
M2	653.2	1311.2	485.7	1292	275.1	2093.5	315.8	801.5	262.3	1926.1	492.9	1380.5	437.9	1296.8
M3	728.7	1175.6	486.5	1112.6	215.3	2148.5	315.8	679.5	251.2	2057.6	344.5	1583.9	488.1	1150.8
M4	684.3	1265.7	513.1	1240.8	272.7	2115.1	358.9	985.7	311	1796.9	480.9	1414	504.9	1344.6
M5	754.8	1158.0	447.4	1248.9	253.6	2136.6	282.3	665.1	238	1997.8	451.3	1476.2	421.1	1567.1
M6	701	1289.6	497.7	1390.1	282.3	2146.1	325.3	701	301.4	1997.8	464.1	1516.9	471.3	1495.3
M7	707.6	1167.0	504.4	844	401.6	2777.3	408.6	888.2	387.2	2254	594.1	1638.8	638.9	1448.6
W1	660.3	1449.9	473.7	1466.7	294.2	2263.3	308.7	976.1	306.3	1871.0	418.7	1780.1	361.3	1945.2
W2	908.4	1401.7	435	1284.2	279	2648	343.9	901.2	327.2	2435.2	466.1	1595.2	475.4	1517.6
W3	801	1327.2	559.4	1547.7	317.7	2466.1	411.2	877.4	394.3	2049.9	571.1	1540.3	592.8	1645.6
W4	918.1	1437.7	542.4	1346.3	290	609.5	344	753.2	332	667	543.3	1800.3	544.3	1304.5
W5	913.3	1439.9	566.6	1844.1	377.6	2827.6	423.1	791.4	403.6	2396.2	444.7	1741.3	494.6	1660
W6	942	1384.9	676.7	1434.9	343.8	2564.1	384.9	769.9	320	2578.8	593.4	1297.9	576	1526
W7	853.4	1463.7	455.6	1414.7	341.7	2595.4	389.6	851.1	322.3	2361.7	512	1717.9	511.4	1643.2

Note. ‘M’ represents male while ‘W’ represents female.

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Table 2 shows that the F1 and F2 values for the seven first-level vowels in Chinese differ between male and female speakers.

In terms of tongue position, for [A], F1 ranges between 653.2 Hz and 942 Hz. The tongue position of M2 is the highest, while W6 is the lowest. F1 of [ɤ] ranges between 435 Hz and 676.7 Hz. The tongue position of W2 is the highest, whereas W6 is the lowest. F1 of [i] ranges between 215.3 Hz and 401.6 Hz. The tongue position of M3 is the highest, while that of M7 is the lowest. F1 of [u] ranges between 282.3 Hz and 423.1 Hz. The tongue position of M5 is the highest, and that of W5 is the lowest. F1 of [y] ranges between 238 Hz and 403.6 Hz. The tongue position of M5 is the highest, and that of W5 is the lowest. F1 of [ʅ] ranges between 344.5 Hz and 594.1 Hz. The tongue position of M3 is the highest, and that of M7 is the lowest. F1 of [ɿ] ranges between 361.3 Hz and 638.9 Hz. The tongue position of W1 is the highest, and that of M7 is the lowest.

Regarding the backness of the tongue position, for [A], F2 ranges between 1095.8 Hz and 1463.7 Hz. The tongue position of M1 is the most backward, and that of W7 is the most fronted. For [ɤ], F2 ranges between 844 Hz and 1844.1 Hz. The tongue position of M7 is the most backward, and that of W5 is the most fronted. For [i], F2 ranges between 1966.7 Hz and 2827.6 Hz. The tongue position of M1 is the most backward, while that of W5 is the most fronted. For [u], F2 ranges between 665.1 Hz and 985.7 Hz. The tongue position of M5 is the most backward, and that of M4 is the most fronted. For [y], F2 ranges between 667 Hz and 2578.8 Hz. The tongue position of W4 is the most backward, and that of W6 is the most fronted. For [ʅ], F2 ranges between 1265.7 Hz and 1800.3 Hz. The tongue position of M1 is the most backward, and that of W1 is the most fronted. For [ɿ], F2 ranges between 1091 Hz and 1945.2 Hz. The tongue position of M1 is the most backward, and that of W1 is the most fronted.

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3.2 Vowel Chart

For a more immediate visual investigation, the vowel charts of the Kazakh-speaking learners are displayed in Figure 1, allowing a comparison of each speaker's tongue position. Consistently, allowing every speaker's tongue position to be fully observed.

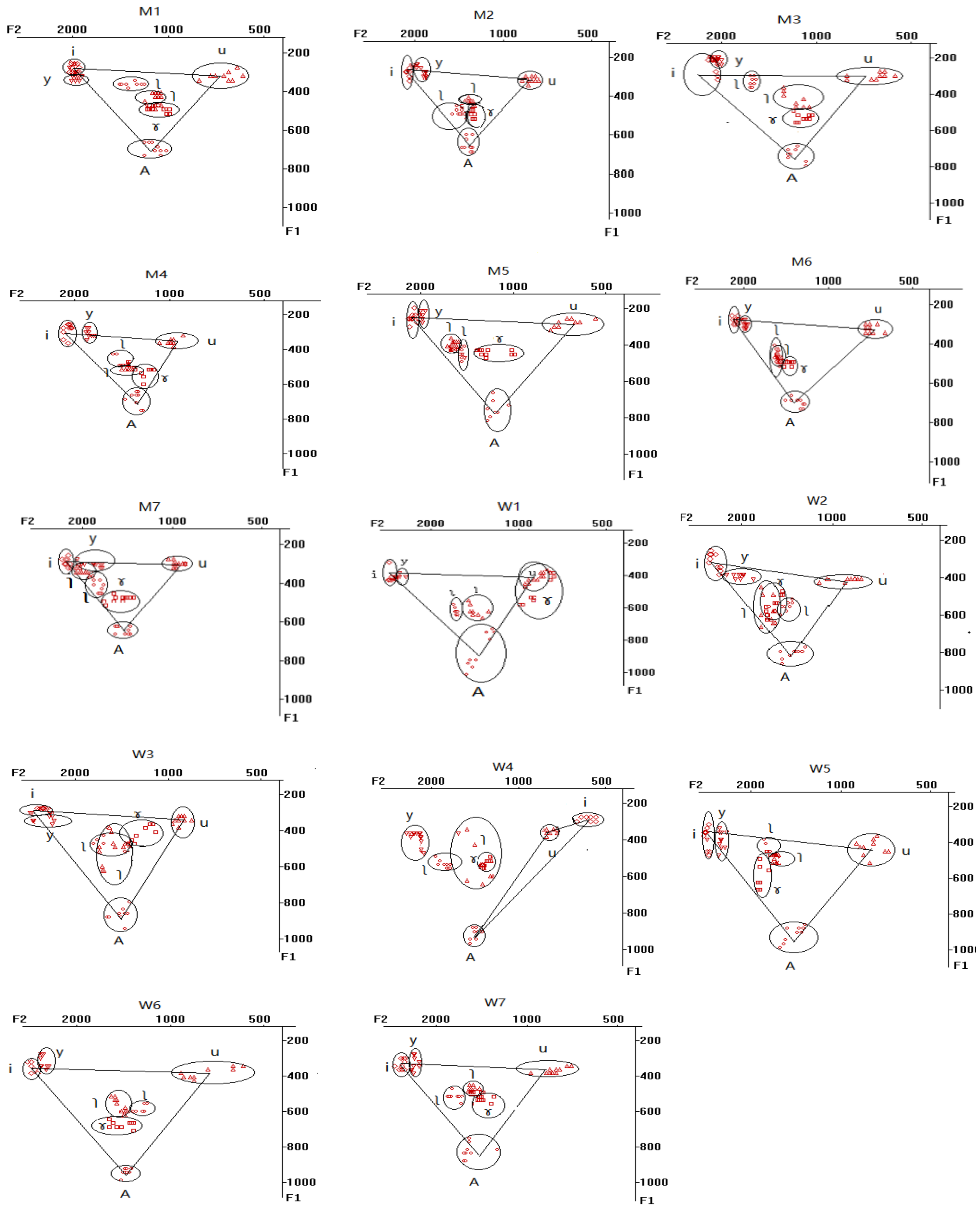

Figure1. The vowel chart of learners group

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From Figure 1, we can deduce the following characteristics of first-level vowel acquisition by the Kazakh students.

First, the shape of most of the vowel charts is an acute triangle formed by three vertex vowels [A], [i], and [u]. The vowel chart of W4 is an obtuse triangle formed by three vertex vowels, which is different from that of the other speakers.

Second, the F1 values of the male learners producing [A] range between 600 Hz and 800 Hz, while the F1 values of the female learners are between 800 Hz and 1000 Hz, suggesting that the tongue position of the female speakers producing [A] is lower than that of the male speakers, which is closer to the position of Chinese in terms of tongue height. Regarding tongue backness, the overall tongue position of the Kazakh learners is more fronted than the Chinese speakers. The tongue position of Kazakh females' production of [i] is more fronted than that of the Chinese speakers. However, the F2 value of the male speakers is around 2200 Hz, which indicates that the tongue position is closer to that of Chinese speakers.

For [u], the tongue position of the Kazakh students deviates somewhat from that of Chinese speakers, mainly because the tongue position is relatively more fronted. The F1 value of [u] is between 200 Hz and 400 Hz, which is close to that of Chinese native speakers in terms of tongue height. The vowels [i] and [y] are next to each other. However, the spatial arrangement of the two vowels is not fixed and varies significantly, with [i] in W4 located near the origin of the coordinates and [y] located lower into the back vowel space. Within the triangle, [ʅ], [ʇ], and [ɤ] are arranged in a more confusing order with significant variation. At the same time, [ɤ] also has a more irregular position with a clear dynamic range.

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4.0 IMPLICATIONS, LIMITATIONS AND FUTURE RESEARCH

Given the challenges in producing apical vowels, specific drills and exercises focusing on these sounds should be incorporated into language instruction for Kazakh learners. The observed gender differences in vowel production imply that instructional strategies might need to be tailored differently for male and female learners to address their specific articulation patterns. The study found that male and female learners exhibit different F1 values when producing [A], indicating varied tongue heights. Tailoring instruction to these differences can help address the unique challenges each gender faces, ensuring that both male and female learners can achieve more accurate pronunciation.

Training should emphasize the correct tongue position, especially for vowels like [i] and [u], to reduce fronting tendencies and improve overall vowel accuracy. The data shows that Kazakh learners, particularly females, tend to front their tongue more than native Mandarin speakers for [i] and [u]. Emphasizing proper tongue placement through targeted exercises can help learners adjust their articulatory habits, resulting in pronunciation that more closely aligns with native Mandarin norms.

The significant variation in the spatial arrangement of certain vowels suggests a need for individualized feedback and practice to achieve more consistent and native-like pronunciation patterns. The study highlights considerable variability in the spatial positioning of vowels like [ɤ], [ʅ], and [ɿ]. Providing individualized feedback allows instructors to address the specific pronunciation issues of each learner, facilitating more precise adjustments and leading to a more consistent and accurate production of these challenging vowels.

Some limitations of the current study warrant attention. First, this study was conducted solely to examine the characteristics of Chinese first-level vowels production by Kazakh Chinese learners. Future studies could compare the Chinese

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first-level vowels production by Kazakh-speaking learners and native Chinese speaker to comprehensively and deeply investigate the pronunciation difficulties by Kazakh L2 learners. Another limitation can be notably observed. The sample of the present study comprises 14 learners. Therefore, the findings may not necessarily be generalizable or definitive. Future work should recruit a large number of participants to enhance the robustness and generalizability of the findings.

5.0 CONCLUSION

Some conclusions can be drawn on vowel pronunciations based on the acoustic analysis of the vowels production by Kazakh Chinese learners.

Most of the vowel charts from the participants form an acute triangle with the vertex vowels [A], [i], and [u]. This is a typical shape observed in vowel charts, indicating certain uniformity in vowel space among most speakers. However, one participant (W4) exhibited an obtuse triangle shape, which suggests a different articulation pattern for the vertex vowels. This deviation indicates individual differences in vowel production that might be influenced by the speaker's native language phonetic background.

Regarding gender differences in vowel production, the F1 values for the vowel [A] show a clear gender distinction. Male learners have F1 values ranging between 600 Hz and 800 Hz, while female learners range between 800 Hz and 1000 Hz. This suggests that female learners produce [A] with a lower tongue position compared to male learners. The lower tongue position for female speakers is closer to the typical tongue height for the Chinese [A], indicating a better approximation to native pronunciation.

For the vowel [i], the analysis shows that Kazakh female learners have a more fronted tongue position compared to Chinese speakers. This is reflected in the higher

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F2 values. Male learners, however, exhibit an F2 value around 2200 Hz, which aligns more closely with native Chinese speakers, indicating a more accurate tongue position for [i] in terms of both height and backness.

Kazakh learners show a more fronted tongue position for [u] compared to Chinese speakers. Despite this, the F1 values for [u] fall within 200 Hz to 400 Hz, like native speakers in terms of tongue height, but the fronted position indicates a potential area for targeted phonetic training.

Within the vowel triangle, the arrangement of [ʅ], [ʅ], and [ɤ] is inconsistent and exhibits significant variation. Particularly, [ɤ] has an irregular position and a clear dynamic range, indicating variability in articulation among learners. This irregularity suggests that these vowels pose more difficulty for Kazakh learners, potentially due to their absence or different realization in the native Kazakh and Russian phonetic systems.

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