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A Study on Fricatives and Affricates Produced by Chinese English Learners

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Abstract: The resemblance between equivalent phonemes in Mandarin and English may be crucial for Chinese English learners. Three pairs of comparable fricative and affricates exit in the two languages. Prior research on fricatives and affricatives has tended to ignore the outputs of second language learners and instead concentrated on those of monolingual speakers. As a result, the research question of the current paper is to study fricatives and affricates produced by Chinese English learners. After extracting the main acoustic features of fricatives and affricates that occurred in both English and Mandarin produced by Chinese English learners, one-way ANOVA tests are used to examine the significance. Multidimensional Euclidean distance is used to compare the similarity between each pair of comparable phonemes. The results of these tests led to the conclusion that Mandarin has a detrimental impact on English when learning a second language. What is also worth noticing is that gender may work in the acquisition process, which needs further research to verify.

Keywords: second language learning, fricatives, affricative, Chinese English learner

1. Introduction

In mandarin, there is a voiceless retroflex fricative /ʂ/ and two retroflex affricatives /ʈʂ, ʈʂʰ/. In General American English (GAE), postalveolar affricates /dʒ, tʃ/ and voiceless postalveolar fricative /ʃ/ play crucial roles in consisting a word. Besides the state of being aspirated and voiced or not, the only difference between the two groups (shown in Table 1) is the place of articulation. Therefore, due to their similarities, it is possible that people who take Mandarin as their mother tongue will be affected when acquiring English [1,2].

Table 1: Two groups of consonants involved in this research.

	Voiceless affricative	**Voiceless affricative (aspirated)**	**Voiceless fricative**
Retroflex	/ʈʂ /	/ʈʂʰ/	/ʂ/
	Voiced affricative	**Voiceless affricative**	**Voiceless fricative**
Postalveolar	/dʒ/	/tʃ/	/ʃ/

Svantesson first focused on Standard Mandarin's fricatives and affricates [3]. Three parameters—spectral centroid, spread, and mean intensity level—were taken from the crucial band spectra to create the fricative pattern. Studies on Chinese dialects and other ethnic languages have also benefited from approach [4,5]. It cannot, however, reliably distinguish between various fricatives and affricates.

Six Standard Mandarin fricatives' energy values were derived by Sun using 162 evenly spaced frequency bands between 2 and 16 kHz [6]. According to principal component analysis, the first three components comprised 94.8% of the data of fricatives.

Eight English fricatives were examined by Jongman and his colleagues using ten acoustic criteria, including spectrum, amplitude, and duration [7,8]. Six spectrum and amplitude-related factors were discovered to be an efficient way to distinguish between the four fricative articulation points.

Ran & Shi conducted an additional study on a few factors utilizing speech pattern research concepts and techniques based on fricative space analysis [4]. Five fricatives from the Beijing dialect are reanalyzed, and the G and D values of fricatives are proposed by normalization and relativism. In the research of Lee et al., Mandarin affricates are proven not to be distinguished through merely one acoustic feature [9].

Lee & Gu examined the connections between acoustic characteristics and phonetic traits for six Mandarin affricates [10]. Praat retrieved the nine acoustic features, which include the duration, amplitude, spectral energy distribution, and F2 start of the subsequent vowel. According to discriminant analysis, combining all nine auditory data provided the six affricates with an 85.9% identification rate. According to a principal component analysis, the first five components supplied 86.3% of the information for the affricates. The most significant auditory factors for Mandarin affricates are the friction's spectrum energy distribution parameters, some of which primarily affect the articulation site. Others, however, are mainly responsible for the condition of ambition.

Most previous studies focused on the fricatives or the affricatives produced by the Chinese. Scarcely any of them mentioned how Chinese English learners produced comparable phonemes in English and the influence committed by the similar ones in their mother tongue. It is significant for Chinese English learners to realize the differences between those comparable phonemes. Figuring out what are the differences and what are the possible reasons is the first step. Therefore, based on the previous study, the hypothesize of this paper is:

The similarity of comparable phonemes in English and Mandarin will affect Chinese English learners' acquisition of them.

The hypothesis will be proved to throw examining the acoustic characteristics of fricatives and affricates that occurred in English and Mandarin produced by Chinese English learners, testing the ability of Chinese English learners to differentiate the comparable phonemes, while concluding the influence of mother language, Mandarin, on English during the second language acquisition.

2. Method

2.1. Participants

Four speakers who take Mandarin as their first language (two males and two females) will participate in the research. All four speakers are junior students in English major and have once been trained in a foreign language school for six years, which ensures their English abilities and positive attitudes toward second language acquisition.

2.2. Materials

Two vowels (/ɑ, u/) are selected to combine with the six consonants in Table 1. Therefore, six words for each language are created as the stimuli used in this research. Some other consonants are used as codas to ensure that all the stimuli (especially English ones) are real words. In total, twelve stimuli are listed in Table 2.

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Table 2: Stimuli used in this research.

	/ɑ/		/u/	
/ʈʂ /	渣 /ʈʂa:/	residue	珠 /ʈʂu:/	bead
/ʈʂʰ/	插 /ʈʂʰa:/	insert	出 /ʈʂʰu:/	out
/ʂ/	沙 /ʂa:/	sand	书 /ʂu:/	book
/dʒ/	jar /dʒɑ:r/		Jude/dʒu:d/	
/tʃ/	char /tʃɑ:r/		chew /tʃu:/	
/ʃ/	sharp/ʃɑ:rp/		shoe /ʃu:/	

2.3. Procedure and Analysis

All the speakers are required to utter the stimuli in Table 2. There are in total 48 audio files are saved in wav form. All in silent experimental environments, recordings are realized as mono soundtracks, ensuring the following analysis's accuracy.

Praat is used to extract the most important acoustic characteristic of each consonant – spectral moment, which includes spectral centroid (1st order moment), standard deviation (square root of the second-order central moment), skewness (normalized third-order major moment), and kurtosis (normalized fourth-order central moment) [10].

Based on the spectral function of the middle 80% duration of the fricative segment, the spectral centroid (i.e., mean), standard deviation, skewness, and kurtosis are calculated. The spectral centroid represents the center position of the energy; the standard deviation represents the dispersion of the spectrum; the skewness indicates whether the energy is mainly distributed in the high-frequency or low-frequency range (positive skewness indicates more energy in the low-frequency range, while negative skewness indicates more energy in the high-frequency range). The kurtosis represents the sharpness or flatness of the energy concentration area. The algorithms used in the research are listed below (f is the frequency):

$$e = \int_0^\infty f \, |S(f)|^p \, df \tag{1}$$

3. Results

3.1. Acoustic Characteristics

The current research's acoustic measurements (spectral centroid (i.e., mean), standard deviation, skewness, kurtosis) are shown in Table.

Table 3: Acoustic characteristics of each speaker.

	F1				M1			
	Spectral Centroid	**Standard Deviation**	**Skewness**	**Kurtosis**	**Spectral Centroid**	**Standard Deviation**	**Skewness**	**Kurtosis**
zha	949.18 7	1144.5 72	3.274	11.3 23	839.3 69	166.9 79	3.61 2	86.0 81
jar	1000.1 12	1385.7 51	3.719	13.3 5	721.1 32	175.5 57	2.37 8	44.5 11

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Table 3: (continued).

cha	1123.515	907.192	3.136	14.229	813.965	229.466	3.051	54.665
char	869.779	759.097	5.584	42.115	738.883	200.889	2.745	72.874
sha	1417.693	1544.709	2.105	3.726	742.533	161.284	2.41	60.874
sharp	1531.871	1591.091	1.819	2.275	749.223	134.091	6.324	211.523
zhu	464.523	824.023	6.218	40.188	531.468	244.464	2.869	68.573
jude	763.939	1253.868	4.03	16.382	514.172	320.414	3.162	53.401
chu	844.996	1390.379	3.526	11.936	591.888	217.262	4.34	120.17
chew	932.326	1403.876	3.096	9.621	469.828	310.597	4.363	68.726
shu	1084.382	1679.568	2.473	5.022	567.796	236.245	5.833	141.941
shoe	1117.351	1706.358	2.269	3.844	559.012	300.696	2.236	37.911

	F2				**M2**			
	Spectral Centroid	**Standard Deviation**	**Skewness**	**Kurtosis**	**Spectral Centroid**	**Standard Deviation**	**Skewness**	**Kurtosis**
zha	429.197	604.578	4.536	30.889	689.736	391.863	2.691	16.63
jar	490.858	561.513	6.094	86.058	676.058	393.226	5.289	62.139
cha	740.83	926.175	3.106	15.606	714.079	310.019	2.317	28.692
char	629.468	629.468	4.058	37.737	628.606	444.773	5.025	51.73
sha	1092.696	1241.657	2.436	11.488	786.884	362.643	6.668	88.446
sharp	999.193	1178.029	2.489	11.722	711.993	318.395	6.043	89.853
zhu	351.329	261.873	16.662	501.075	310.645	235.017	14.955	357.457
jude	374.002	336	15.056	401.449	332.309	261.398	15.436	334.625
chu	355.487	398.635	19.046	534.074	338.749	342.323	12.966	216.327
chew	528.183	721.634	5.996	58.49	369.522	387.355	13.155	200.559
shu	419.813	820.224	10.468	146.319	345.97	462.854	10.108	120.338

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Table 3: (continued).

shoe	639.572	976.262	5.729	56.204	348.826	445.349	11.411	150.122

The method of numeric outlier is used to calculate the IQR (Inter Quartile Range) to examine the nonparametric outliers. Box plots for the results of the test are presented below. Two outliers in the spectral centroid's data are displaced from the four figures. Meanwhile, more outliers are displaced in Figures 3&4, which indicates that the data from extracted skewness and kurtosis are non-convergent. This phenomenon may be explained in two ways. First, unlike spectral centroid and standard deviation, skewness and kurtosis are more personalized. Speakers may produce them differently due to their biological differences. Moreover, the limitation of sample size may also be a reason for the outliers, which could be further examined with a larger sample size.

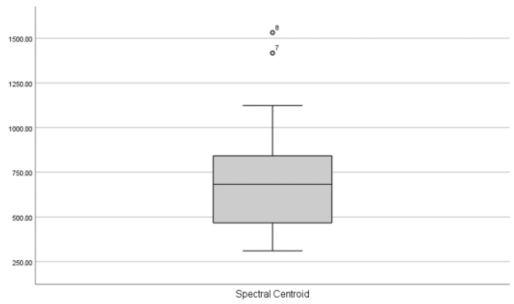

Figure 1: Box plot of spectral centroid.

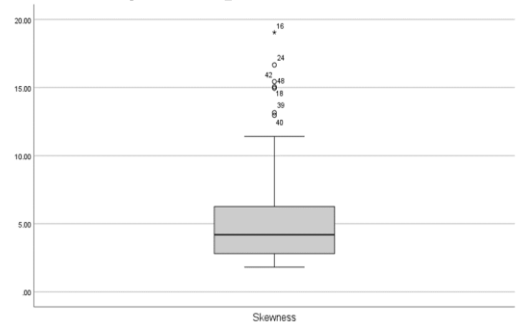

Figure 3: Box plot of skewness.

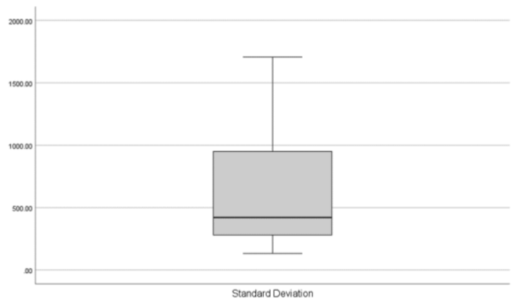

Figure 2: Box plot of standard deviation.

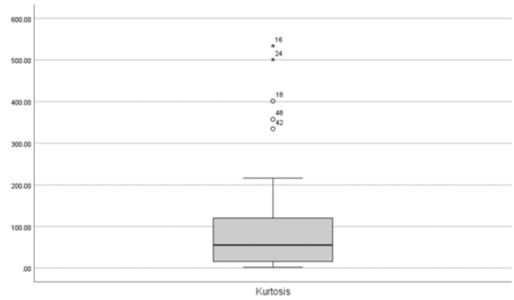

Figure 4: Box plot of Kurtosis.

A one-way ANOVA was performed to compare the effect of language on each acoustic characteristic for the three comparable groups. This test includes 4 speakers * 2 vowels * 6 comparable phonemes = 48 acoustic features that are extracted to be compared with different languages. The results are listed below in Table 3. It revealed that there was no statistically significant difference in the four characteristics in all three groups, which indicates that language is not one of the main factors influencing a speaker's producing fricatives and affricatives differently. These findings at least hint that participants, representatives of professional English learners with Mandarin as their mother tongue, have difficulty in differentiating the comparable fricatives and affricates that occurred in both English and Mandarin.

Table 4: Summary of results of ANOVA tests for each comparable group.

	/ʈʂ /-/dʒ/		**/ʈʂʰ/-/tʃ/**		**/ʂ/-/ʃ/**	
	F	**Sig.**	**F**	**Sig.**	**F**	**Sig.**

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Table 4: (continued).

Spectral Centroid	0.151	0.703	2.094	0.17	0.018	0.895
Standard Deviation	0.007	0.934	0.268	0.613	0.003	0.955
Skewness	0.143	0.711	1.138	0.304	0.094	0.763
Kurtosis	0.721	0.41	1.01	0.332	0.003	0.958

3.2. Euclidean Distances

After the four characteristics are extracted, Euclidean distance is used to test the similarity between the comparable phonemes in each group. In mathematics, the Euclidean distance between two points in Euclidean space is the length of a line segment between the two points. It can be calculated from the Cartesian coordinates of the points using the Pythagorean theorem, occasionally called the Pythagorean distance.

The distance between two objects that are not points is usually the smallest distance between pairs of points from the two objects. Formulas are known for computing distances between different types of objects. The formula is listed below:

$$d = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \tag{2}$$

The distances between each comparable phoneme are listed in Table 4. The displacement of distances is shown in Figure 5, where the values are most gathered in the range under 300.

Table 5: Euclidean Distances between each comparable phoneme.

	/ʈʂ /-/dʒ/		/ʈʂʰ/-/tʃ/		/ʂ/-/ʃ/	
	/ɑ/	**/u/**	/ɑ/	**/u/**	/ɑ/	**/u/**
F1	246	524	295	88	123	42
F2	93.29	126.24	317.69	600.42	113.1	284.23
M1	125.63	79.36	82.37	162.04	153.28	122.74
M2	47.61	41.07	161.25	56.78	87	34.69

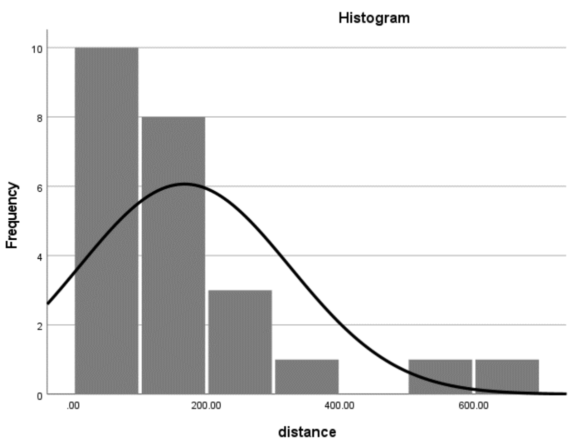

Figure 5: Histogram of the calculated distance.

Table 6: Results of K-means cluster for distance.

Final Cluster Centers		
	Cluster	
	1	2
Distance	122.13	480.70
Number of Cases in each Cluster		
Cluster	1	21
	2	3
Valid		24

The classic distance-based clustering algorithm is used here to separate these calculated distances into two degrees. Due to the limited sample size, the number of cluster groups was set as two. The result of the K-means cluster is shown in Table 5. The final cluster centers after ten iterations are 122.13 for group one and 480.7 for group two. Since the smaller the distance is, the similar the pronunciations of the comparable phonemes are, group one refers to a worse degree of differentiation. In contrast, group two refers to a better one. Only 12.5% (three out of twenty-four) of the calculated distances belong to group two, which represents the deficiency of Chinese English learners' abilities to differentiate similar fricatives and affricatives that occurred in both English and Mandarin.

3.3. Gender

As the last research orientation for the present experiment, the effect imparted upon the ability to differentiate similar phonemes by gender is elaborated in this part. Gender has already appeared as an environmental condition antecedently, while the following main content is to expound its effect on speech with the statistical support in Table 6.

A one-way ANOVA was performed to compare the effect of gender on distances between comparable phonemes. This test includes 4 speakers * 2 vowels * 3 pairs of comparable phonemes = 12 Euclidean distances that are compared with in genders. The results revealed that there were statistically significant differences in the groups of spectral centroids (F=7.414, p = .009) and standard deviation (F=62.893, p =.000). In contrast, no statistically significant difference was found in the groups of skewness (F=.157, p =.694) and kurtosis (F=.577, p =.451).

Table 7: Results of the ANOVA test for the factor of gender.

	F	Sig.
Spectral Centroid	7.414	.009
Standard Deviation	62.893	.000
Skewness	.157	.694
Kurtosis	.577	.451

There are two possible explanations. First, gender affects the ability to differentiate the comparable phonemes during second language acquisition for Chinese English Learners in terms of study attitudes, study methods, and cognitive ability in different genders, which requires further study to verify. However, this difference may be caused by biological differences between the two genders.

4. Discussion

This deficiency in differentiating the comparable fricatives and affricates in English and Mandarin may derive from the inability to distinguish these phonemes auditorily. Since English learners sensed no difference, they spontaneously replaced such phonemes with their similar counterparts in Mandarin. To improve the situation, Chinese English learners may listen more carefully to the audio of native English speakers and acquire the pronunciations from articulation places and articulatory matters with the help of professional linguistics.

The similarity between comparable phonemes in English and Mandarin may be crucial for Chinese English learners. Exploring the differences and testing students' ability to differentiate is one of the steps of concurring the difficulties brought by it.

Previous studies on fricatives and affricatives most focus on monolingual speakers' productions but neglect the ones of second language learners. The results from this paper can remind Chinese English learners and Chinese English teachers to pay more attention to the pronunciation of fricative and affricates in English. Therefore, improve the ability to differentiate them from their counterparts in Mandarin.

The sample size of the current study is limited. Future studies could enlarge the number of participants and stimuli to obtain a more precise result. In addition, only four acoustic characteristics are involved in this study. More relative features could be involved in the following studies.

5. Conclusion

Based on a series of results and discussions, some conclusions with more generality and universality are drawn. The acoustic measurements extracted and the Euclidean distances calculated followed. The hypothesis of this paper can be proved that the similarity of comparable phonemes in English and Mandarin affects Chinese English learners' acquisition of them. Moreover, the effect is negative. Last, gender also affects the ability to differentiate the comparable phonemes. The results of this research can help Chinese English students and teachers better learn and teach English as a second language. Last but not least, the limitation of this research is also analyzed.

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