An Experimental Study on the Intelligibility of English Fricatives by Cantonese and Mandarin Speakers

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Abstract. English pronunciation can vary significantly depending on different speakers' accents. In one of Chinese dialects, Cantonese-speaking regions, where Cantonese has led to English pronunciation properties in communicative and teaching activities. To address this situation, this research conducted an experiment to test the intelligibility of Cantonese English speakers focused on the features of English fricatives. The results in three perspectives in terms of three types of sound according to Flege's Speech Learning Model (new sound, similar sound, identical sound), places of articulation, and different phoneme distribution environments. The data show detailed features on intelligibility of English fricatives between English and Cantonese and may lay the groundwork for further studies on the intelligibility of English fricatives between Chinese dialects and English. This study may serve as a reference for both educators and learners regarding potential problems with English pronunciation in Cantonese-speaking regions, and also provide some scientific data and theoretical values for Artificial Intelligence technologies, especially in the fields of speech production and speech recognition.

Keywords: intelligibility, fricatives, Cantonese, English

1 INTRODUCTION

English, as the most spoken language in the world, is the most widely learned second language [1]. Meanwhile, Chinese is a language with a great variety of dialects, including Cantonese, which has been spoken by over 120 million people in the Guangdong-Hong Kong-Macao Greater Bay Area back in 2013 [2]. The rapid economic growth has made this region "a window to the world," leading to a high demand for international communication and, thus, for English education. However, native Cantonese speakers are facing challenges in learning English, which has aroused significant attention [3]. It is noticeable that English pronunciation varies based on accents influenced by hometowns, educational backgrounds, and experiences [4]. Cantonese, being one of the Chinese dialects, has been found to affect English pronunciation and intelligibility. Plus, with more and more artificial intelligence (AI) assistants (e.g. Amazon's Alexa, Apple's Siri, and etc.) applied in people's daily lives, phonetics-related studies play an important role in the AI time, especially in speech recognition.

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This research aims to the intelligibility of fricatives among Cantonese English speakers. By comparing Cantonese and Mandarin speakers' identification of English fricatives, we can explore the impact of Cantonese and Mandarin accents on English fricatives' intelligibility.

In the 1960s and early 1970s, Lado's Contrastive Analysis (CA) Hypothesis [5], claiming that "Individuals tend to transfer the forms and meanings and the distribution of forms and meanings of their native language and culture to the foreign language and culture", was extensively applied in the field of SLA. The transfer could be either positive or negative, which can be found in both speech production and perception.

However, Flege's theory of Equivalence Classification [6] had proven Lado's theory assailable. According to his Speech Learning Model (SLM), besides the identical sounds that share identical articulations and the same IPA symbol between the native language (L1) and foreign language (L2), he had classified L2 sounds as either "new" or "similar" based on their acoustic similarity to sounds in the L1 [6]. Similar sounds are those that are acoustically similar to sounds in the L1, new sounds are those that do not have a counterpart in the L1, which are transcribed with a new IPA symbol that does not exist in the native-language inventory. For similar phones, L2 learners are likely to perceive the familiar L2 vowels as being equivalent to their L1 counterparts. As a result, he regarded the identical phones are the easiest for the second learners, and new phones with distinctive differences stand in the middle, while similar phones are the hardest to learn.

Current research focuses on the contrastive analysis between English and Cantonese mainly especially on the phonetic transfer during the second language acquisition [7]. As for the previous domestic studies on consonants by Cantonese EFL speakers, most of them focused on nasals [8], stops [9-11], and fricatives [11].

Cui (2020) conducted experiments including productive and perceptual tests to study the production and perception of coda nasals by speakers of Cantonese and Mandarin. Thus, Jia (2011) studied the negative transfer of English coda voiceless plosives from Cantonese to English by error analysis on Cantonese students and Mandarin speakers. In 2015, Zhou and Chen (2021) carried out an experiment with the software PRAAT to test the production of onset stops by high school students, whose native language is Cantonese. Besides, Chen took research on English fricatives and stops produced by Cantonese students majoring in English.

As a significant measurement dimension in the SLA study, intelligibility was defined by Munro [12-13] as "the extent to which the native speaker understands the intended message", generally applied in measuring by articulating correctness. There have been many previous studies aiming at measuring this dimension through experiments, Wang conducted an experiment measuring the mutual intelligibility of English speakers in China, Dutch, and America [14]. Later, Wang launched a study on English vowel perception [15].

However, till now, studies on the intelligibility of English fricatives, especially those concerning the comparison between Chinese dialects and English are far less than adequate. Even if there is research between Cantonese and English, few are in relation to the intelligibility research. Therefore, this research is to study the intelligibility of English fricatives produced by Cantonese ESL learners.

A fricative is defined as a consonant produced by forcing air through a narrow channel made by placing two articulators close together [16]. In English, there are nine fricatives in total,

including labiodentals /f/, and /v/, dentals /θ/, and /ð/, alveolars /s/, and /z/, post-alveolars /ʃ/, and /ʒ/, and a glottal /h/; of which sound /h/ is excluded from our range of study for its natural constancy in articulation among languages.

As for Mandarin and Cantonese language systems, since Cantonese is a variation of ancient Chinese, they share common characteristics in the field of fricatives. Comparing four fricatives in Mandarin (sounds /x/ and /h/ are excluded for the same reason as the former English /h/) with two in Cantonese, /f/ and /s/ share the common manner as well as the place of articulation, while sounds /ʂ/ and /ɕ/ especially existed in Mandarin.

In the context of this experiment, according to Flege's theory and his definition of identical sounds, similar sounds, and new sounds, /f/ and /s/ that both appear as the identical phonetic symbol in IPA between Cantonese and English are identical sounds, while /v/ and /z/ which share the same places of articulation with the identical sounds are defined as similar sounds in Cantonese, and the four rest fricatives that especially exist in English articulatory system /θ/, /ð/, /ʃ/ and /ʒ/ are new sounds to Cantonese. The comparison of fricatives that appeared in the language systems of English, Mandarin, and Cantonese is represented in Table 1 [17-18].

Table 1: Phonetic symbols of fricatives among Mandarin, English, and Cantonese

Manner	Place of Articulation								
	labial	labiodental	dental	alveolar	post-alveolar	retroflex	palatal	velar	glottal
Source: Mandarin									
Fricative		f		s		ʂ	ɕ		
Source: English									
Fricative		f v	θ ð	s z	ʃ ʒ				
Source: Cantonese									
Fricative		f		s					

According to the theories above, for the second language of Cantonese accented English speakers, their learning process of English tends to be influenced by their native language. Moreover, the intelligibility of the identical sounds, similar sounds, and new sounds produced by Cantonese, Mandarin, and English speakers might also be different.

To narrow the gap of studies on English fricatives by Chinese dialect speakers, our study is to conduct a production experiment and a perception experiment to test the intelligibility of English fricatives produced by speakers with language backgrounds of Cantonese, Mandarin, and English, and to address the following questions.

1. How well is the intelligibility of the identical sounds, similar sounds and new sounds respectively produced by Cantonese speakers?

2. Do the perception results match Lado and Flege's theories? In terms of the same group of listeners, will the similar sounds they produce show the worst intelligibility than new sounds produced by all speakers, while the intelligibility of identical sounds shared by English and Cantonese shows the best?

3. Does the intelligibility of the fricatives relate with different places of articulation? If yes, which shows the best intelligibility, and which the worst?

4. Do the different positions of fricatives affect their perception? If so, how well is the intelligibility of fricatives in the environments of /a:C/, /Ca:/, and /a:Cə/ respectively?

2 METHOD

The method of this experimental study will be elaborated in 3 parts: the selection of subjects, materials and the procedure of the whole experiment.

2.1 Subjects

To test the intelligibility of English fricatives influenced by Cantonese accents, two groups of participants were recruited, one for production, and the other for perception. All of them are from Shenzhen University.

As for the selection of speakers, considering the fact that the samples should be comprehensive, six speakers from three language groups were recruited, Cantonese accented English speakers, non-Cantonese accented English speakers from Mandarin-speaking areas, and English native speakers from English-speaking countries and regions. Each language group consisted of one female speaker and one male speaker. In addition, the experiment plugged in a number of variables such as ages, majors, occupations, and language study backgrounds. Therefore, majors of speakers vary from Civil Engineering, Law, to Architecture, and two of the participants are foreign teachers at the School of Foreign Languages. Since their age range is between 18 to 36, there is an age gap among all the subjects. Besides, non-native English subjects were students who have not majored in English and have not spent a relatively long time in the English language environment.

The selection of listeners remained the same across three distinct groups. Aiming at ensuring credibility, the number of listeners was much more compared to the speaker group, 12 people in total. Listeners should consist of different sexuality and different nationalities in order to control the variable of the experiment. However, due to the limitation of COVID-19, we encountered difficulties in recruiting foreign participants. As a result, our listener group only consisted of participants who are native speakers of Cantonese and Mandarin. And the requirements for them were consistent with the non-native English speakers in the production group, who were students from non-English-related majors have not exposed to English-speaking environments. There are inner differences among these listeners as well. First, listeners are of different ages, varying from 18 to 23. And they major respectively in History, Psychology, Software Engineering, and so on.[1]

2.2Materials

The current study consists of two parts: production and perception.

The targeted fricatives were divided into four groups according to their places of articulation, labial-dentals /f/ and /v/, dentals /θ/ and /ð/, alveolars /s/ and /z/, and alveolar-palatals /ʃ/ and /ʒ/. To test the intelligibility of the fricatives concerning their distribution environments, the target

[1] Please contact writers for more basic information of the production and perception groups.

consonants C were respectively presented in the frameworks of /Ca:/, /a:Cə/ and /a:C/. Speakers produced them in a fixed carrier sentence "I say ~ again" to simulate the natural contexts. All the sentences were written in a reading list and printed on sheet (see Table 2). In case of participants' lack of knowledge of IPA (International Phonetic Alphabet), reminders were attached to the reading list for certain phonetic alphabets, such as /θ/ as in "**th**ink", /ð/ as in "**th**ese", /ʃ/ as in "**sh**oes", and /ʒ/ as in "mea**s**ure". Overall, the material in the production experiment consists of three units, and each one consists of eight items. During the experiment, each speaker should read 24 sentences out loud, and the recordings of their reading process were edited and played to the listeners in the perception experiment.[2]

Table 2: Stimulus in the production experiment

fricatives / structure	/f/	/v/	/s/	/z/	/ʃ/	/ʒ/	/θ/	/ð/
/Ca:/	/fa:/	/va:/	/sa:/	/za:/	/ʃa:/	/ʒa:/	/θa:/	/ða:/
/a:C/	/a:f/	/a:v/	/a:s/	/a:z/	/a:ʃ/	/a:ʒ/	/a:θ/	/a:ð/
/a:Cə/	/a:fə	/a:və/	/a:sə/	/a:zə/	/a:ʃə/	/a:ʒə/	/a:θə/	/a:ðə/

2.3Procedure

Before the experiments, speakers and listeners were given an experiment instruction, including payments, process, time, and the reminders of the targeted sounds.

For the production experiment, two Mandarin speakers, two Cantonese speakers, and two English native speakers were respectively invited to a quiet room at Shenzhen University. Before the experiment, speakers were given enough time to get acquainted with the reading list and its instructions, while receiving guidance from researchers including notices like "trying to read the sentences once only", "repeating the whole sentence if wrongly pronounced" etc. The whole reading process was recorded with a Sony digital recorder, lasting for around two minutes for each speaker, and saved in the format of WAV. After the recordings were transferred onto the computer and double-checked, speakers were allowed to leave the room.

The productions by the speakers were edited with the software Praat. There are six speakers in this experiment, and each speaker produces 24 sentences containing stimulus, 144 sound files in total, which were used as the materials for the listening experiment. They were presented in three parts according to the distributions of fricatives (i.e., /a:C/, /Ca:/, and /a:Cə/), and each part was divided into six groups. To avoid the interference of distraction at the beginning and the end of the experiment, three extra recordings were added respectively. Therefore, there are 150 pieces of recordings in total for the listening experiment.

The perception experiment was performed in a quiet room in the library of Shenzhen University, lasting around one hour for each listener. To minimize interference, each participant came to the room individually and wore wired earphones during the experiment. After being introduced to the design of the experiment and other instructions, listeners had enough time to read the answer sheet and its instructions in both Chinese and English. During the experiment, each

[2] Please contact writers for detailed reading list and its instruction.

sound file was played twice, and there were two or three-second pauses between each play and five-second pauses between each group. The listeners were required to choose the fricatives they heard on the answer sheet[3]. After the experiment, researchers transferred the answers from the answer sheets to an Excel table on the computer immediately and checked if participants jumped some questions during the process.

3 RESULT ANALYSES

3.1 The accuracy of three different sounds

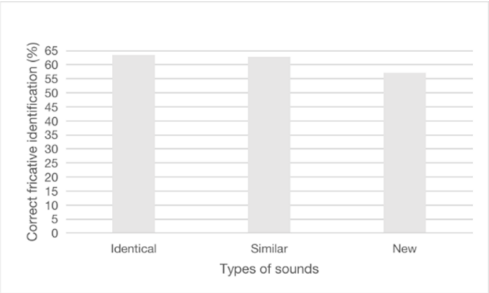

Figure 1: The comparison among accuracy of three types of sounds

Figure 1 illustrates the comparison among the accuracy of three different types of sounds, including the identical sounds /s/, /z/; similar sounds /f/, /v/; and new sounds /ʃ/, /ʒ/, /θ/, and /ð/. By contrast, the accuracy of the identical sounds is among the highest, at 63.43%, only 0.7% higher than the similar sounds. The accuracy of new sounds is relatively low, at the rate of 57.06%. With the identical sounds ranking the highest among three types of sounds, our study's result seems to be only partly compatible with Flege's Speech Learning Model [19]. However, similar sounds, which ought to perform the lowest accordingly, represent the second highest followed by new sounds.

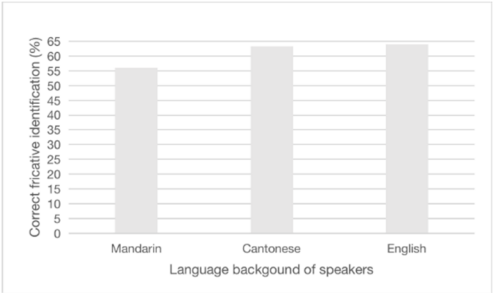

Figure 2: The comparison among intelligibility of three language groups

[3] Please contact writers for detailed answer sheet and its instruction applied in this experiment.

Figure 2 compares the intelligibility of three language groups. According to the data, the identification performance of listeners varies when listening to materials produced by Mandarin, Cantonese, and English speakers. Overall, the listeners show the best result while listening to English native speakers, with an intelligibility of 63.89%, closely followed by the figure for Cantonese speakers (63.20%). In comparison, the lowest intelligibility is 56.13%, which indicates listeners have the worst recognition when listening to recordings of Mandarin speakers. The reason why the perceptual intelligibility of Cantonese speakers outperforms Mandarin ones may be relevant to the selection of subjects. Mandarin speakers involved in this experiment are generally younger compared to Cantonese speakers, with an average age of only 19. This may result in a shorter period of exposure to an English studying environment and a more limited English learning experience, leading to relatively worse performance in intelligibility.

3.1.1The accuracy of identical sounds /f/ and /s/

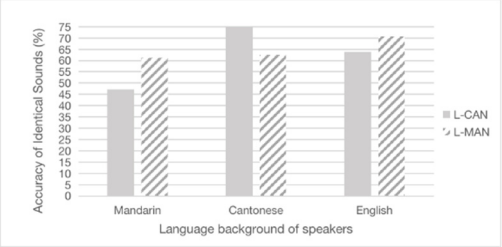

Figure 3: Accuracy of identical sounds from three language groups

Figure 3 compares the perception accuracy among different types of listeners in terms of the identical sounds produced by different speakers. Overall, the accuracy difference between Cantonese listeners and Mandarin listeners indicates better performance of the latter one, with a percentage of 8.33% higher than the Cantonese listeners. According to the Perceptual Magnet Model proposed by Kuhl, materials and speech models from native language have a magnet effect, which will interfere with second language learners in their listening and identification process [20]. As for Cantonese listeners, the perception accuracy rate shows its highest as 75% when recognizing sounds produced by Cantonese speakers, followed by English speakers, 63.89%, and Mandarin speakers, 47.22%, which is compatible with her theory. However, Mandarin listeners' perception of Mandarin speakers and Cantonese speakers' production are similar, with the latter slightly higher than the former by 1.39%, and English speakers the highest, at the rate of 70.83%.

3.1.2The accuracy of similar sounds /v/ and /z/

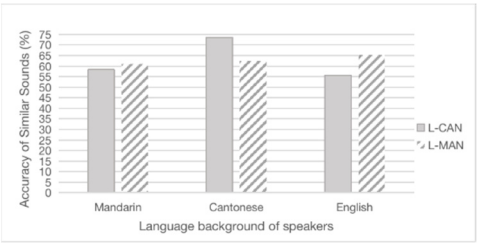

Figure 4: Accuracy of similar sounds from three language groups

Figure 4 shows the accuracy of Cantonese and Mandarin listeners in distinguishing between the similar sounds /v/ and /z/. Overall, Mandarin listeners outperformed Cantonese listeners, but the difference was relatively small (1.39%). The data shows that 18% of the voiced labiodental fricative /v/ produced by Mandarin and English speakers is mistaken as its voiceless counterpart /f/, while 20.8% of the voiced alveolar fricative /z/ is mistaken as the voiceless /s/. These phenomena may result from the fact that there are no voiced consonants in Cantonese, so Cantonese speakers tend to replace voiced English consonants with their voiceless counterparts at the same place of articulation, which may lead to cognitive biases.

The data indicates that Cantonese listeners have the highest accuracy on the materials produced by Cantonese speakers, with a proportion of 73.61%, which corresponds to the Perceptual Magnet Theory. By contrast, their intelligibilities for Mandarin and English productions are much lower, with 58.33% and 55.5% respectively.

3.1.3The accuracy of new sounds /ʃ/, /ʒ/, /θ/, and /ð/

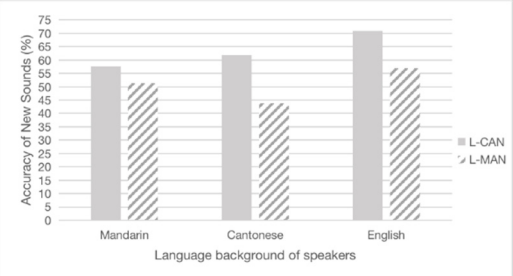

Figure 5: Accuracy of new sounds from three language groups

As for the new sounds /ʃ/, /ʒ/, /θ/, and /ð/, Figure 5 indicates the identification results of Cantonese and Mandarin listeners for speakers from three language groups. Generally, the Cantonese listeners perform better than the Mandarin ones, with a percentage of 12.74% higher than the Mandarin listeners.

Given that the native English speakers produced the most standard pronunciations of the materials, it is reasonable that both of the listener groups have the best performance on the materials produced by English native speakers, with an accuracy of 70.83% (the Cantonese listeners) and 56.94% (the Mandarin listeners) respectively. Both groups also perform better while listening to the materials produced by speakers of their native language, which aligns with Kuhl's theory.

Besides, in the perception tests on the recordings of Mandarin and Cantonese speakers, Cantonese listeners have perceptual accuracies of 57.64% and 61.81%, which are around 6% and 18% higher than the those of Mandarin listeners.

Table 3: The frequency and accuracy of new sounds

	/ʃ/	/ʒ/	/θ/	/ð/
Frequency	178	129	90	96
Percentage	82.41	59.72	41.66	44.44

Additionally, Table 3 shows the frequency and accuracy of the four new sounds. The voiceless post-alveolar fricative /ʃ/ is identified most accurately, with a percentage of 82.41%, which is 22.69% higher than the second-most accurate sound, the voiced post-alveolar fricative /ʒ/. The intelligibilities of the dental fricatives /θ/ and /ð/ are close, at 41.66% and 44.44%, respectively.

According to the data, as for the voiceless dental fricative /θ/, 58 out of 130 wrong answers mistake /θ/ as /s/, while 41 of them mistake it as /f/. As for the voiced dental fricative /ð/, 47 out of 126 wrong answers are /z/ and 27 of them are /θ/. Both of these cases show that Chinese EFL learners are not familiar with and still confused by the dental fricatives /θ/ and /ð/.

3.2The comparison of intelligibility among places of articulation

Table 4: The frequency and accuracy in terms of four places of articulation of fricatives

	Labiodental /f/ and /v/	dental /θ/ and /ð/	Alveolar /s/ and /z/	post alveolar /ʃ/ and /ʒ/
Average frequency	157.5	93	115	153.5
Average percentage	72.92	43.03	53.24	71.07

Table 4 compares the frequency and accuracy of fricatives according to four places of articulation. Notably, labiodentals /f/ and /v/ take up the highest intelligibility (72.92%), closely followed by post-alveolars /ʃ/ and /ʒ/ (71.97%). However, alveolars /s/ and /z/ have a relatively low intelligibility of 53.24%. Furthermore, dentals /θ/ and /ð/ show the lowest accuracy of 43.03% among the four places of articulation.

3.3The comparison of intelligibility among fricatives in three environments

Table 5: The frequency and perceptual accuracy of fricatives in three distribution environments

	/a:C/	/Ca:/	/a:Cə/
Frequency	277	372	377
Accuracy	48.09	64.58	65.45

Table 5 shows the average perceptual accuracy of eight fricatives in three distribution environments, /a:C/, /Ca:/, and /a:Cə/.

Despite the different language backgrounds of speakers, the intelligibility of the /Ca:/ and /a:Cə/ environments is close. However, the accuracy of the /a:C/ environment is the lowest, with a percentage of only 48.09%, around 17% lower than the others. The reason for these results may be that the vowels form the background against which the consonantal constrictions can be heard [21], so the distributions of /Ca:/ and /a:Cə/ could better preserve the articulatory features of fricatives, which could be more intelligible for listeners to perceive the targeted sounds.

3.4Detailed classification of fricatives by Mandarin listeners and Cantonese listeners

Table 6: Classification of fricatives by Mandarin listeners

		/f/	/v/	/θ/	/ð/	/s/	/z/	/ʃ/	/ʒ/	unknown
	/f/	82	15	2	2	1	1	2	0	3
	/v/	13	89	0	0	2	1	1	1	1
	/θ/	18	5	39	9	32	2	0	0	3

Fricatives intended by speakers	/ð/	5	8	13	37	5	28	0	2	10
	/s/	0	0	28	6	59	11	2	0	2
	/z/	0	2	11	26	18	47	1	1	2
	/ʃ/	1	0	3	0	2	0	88	5	9
	/ʒ/	0	1	5	6	4	1	21	55	15

Table 7: Classification of fricatives by Cantonese listeners

		/f/	/v/	/θ/	/ð/	/s/	/z/	/ʃ/	/ʒ/	unknown
Fricatives intended by speakers	/f/	71	18	18	0	0	0	1	0	0
	/v/	16	73	13	2	1	0	0	1	2
	/θ/	24	2	46	6	26	2	0	2	0
	/ð/	6	9	14	52	2	19	1	0	5
	/s/	1	0	18	2	62	19	2	4	0
	/z/	0	1	3	15	21	62	1	2	3
	/ʃ/	0	0	0	0	2	1	90	13	2
	/ʒ/	1	1	2	2	4	3	16	62	17

According to Tables 6 and 7 [22-23], fricatives intended by speakers can be recognized as distinct non-target fricatives. For Mandarin listeners, the dental fricative /θ/ is mistaken for the alveolar-palatal fricative /s/ 32 times, which is only 7 times less frequent than the intended sound by speakers. The same case applies to the identification of fricative /ð/. Its confusable counterpart is the alveolar fricative /z/, which has been identified as intended /ð/ 28 times. In addition, the alveolar-palatal sound /ʒ/ is confused with /ʃ/ by Mandarin listeners 21 times. Consistent with Mandarin listeners, the Cantonese group exhibits similar identification errors. As for the dental fricative /θ/, Cantonese listeners tend to recognize it as /f/ and /s/ with occurrence probability of 24 and 26 respectively. Moreover, the sound /z/ is likely to be identified as the alveolar fricative /s/ by Cantonese subjects, with a frequency of which is 21. Besides, among all the fricatives involved, the recognition of the sound /ʒ/ yields outstanding unknown results, which cannot be distinguished by Cantonese listeners 17 times.

4 CONCLUSION

Based on the data analysis above, our overall findings of intelligibility of English fricatives in terms of three types of sounds, places of articulation, and different environments are as follows. The overall perceptual results, which are consistent with the intelligibility of Cantonese speakers, are partly in accordance with Flege's theories, with the identical sounds still ranking the highest, followed by similar sounds and new sounds (62.73% and 57.06% respectively). As for places of articulation, the intelligibility of the labiodental fricatives /f/ and /v/ and the post-alveolar fricatives /ʃ/ and /ʒ/ are better than the alveolar fricatives /s/ and /z/ and the dental fricatives /θ/ and /ð/. From the perspective of different distribution environments of targeted fricatives, the

intelligibility of /Ca:/ and /a:Cə/ is close, while the accuracy of /a:C/ is the lowest, about 17% lower than that of the others. However, the COVID-19 pandemic limited our native English listeners recruits on campus, therefore, our perception group only involved Cantonese and Mandarin listeners. Furthermore, the average age of Mandarin speakers is rather younger than other language groups, leading to less English learning experience and further under-performance in materials production.

By finding out different levels of intelligibility in English fricatives between Mandarin speakers and Cantonese speakers, this study functions as a reference for Cantonese EFL learners, providing some scientific data and theoretical values for AI technologies (esp. speech production and recognition), English phonetics education in Cantonese speaking regions, and further studies on the intelligibility of English fricatives between Chinese dialects and English.

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