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# The Production of Mandarin Voiceless Sibilant Fricatives by Late Cantonese-Mandarin Bilinguals: an Acoustic Study

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## Abstract

It has been repeatedly suggested that there are L1 interference and gender-related differences in second language acquisition. This study aims to investigate L1 transfer and sex effect on fricative learning by comparing the spectral peak value of the target fricatives /s ʂ ɕ/ and F2 onset of their following vowels produced by late Cantonese-Mandarin bilinguals and L1 Mandarin speakers. The results indicated that there were significant gender effects in /s/ and /ɕ/, yet no significant gender effect in /ʂ/. And there were statistically significant differences in /s/ and /ʂ/, but no significant differences in /ɕ/ between the two language groups.

**Keywords:** L1 transfer; Mandarin voiceless fricatives; Gender-related difference; Spectral peak; F2 onset.



## 1. Introduction

Second language acquisition is complex process which involves every linguistic module like syntax, semantics, phonology and pragmatics. In the field of second language research, the studies on syntax and semantics acquisition have been mature and adequate, yet the studies on phonetics and phonology remain relatively scarce as this research field has been ignored by researchers in the past decades. In fact, the acquisition of phonetics and phonology plays a crucial rule in successful second language (hereafter, L2) acquisition. Accurate perception and production of the target language speech is a prerequisite of effective and understandable communication. However, it has been repeatedly reported that most late bilinguals or L2 learners failed to achieve native-like proficiency no matter in segmental level or suprasegmental level (Major, 2001). Hence, "foreign accent" is often observed in late bilinguals or L2 learners.

Flege (1995) defined "foreign accent" as bilinguals' or L2 learners' deviation from native language in segmental and suprasegmental level, of which the influential factors include language experience, learning environment, age of learning, language background (the learner's native language) and L2 proficiency level and so on (Major, 2001). Among these factors, the influence of native language attracted broad attention. When learning a second language, the learner is inevitably influenced by his native language, termed as "language transfer" (Weinreich, 1953). Language transfer can be positive that promotes L2 learning, and can be negative that hinders L2 learning (Lado, 1957).

When it comes to cross-language influence, the well-known model, Speech Learning Model (hereafter, SLM) firstly put forward by Flege in 1995, makes great contribution to our understanding. The core of SLM is the term "Equivalence Classification", of which the degree determines the learnability of an L2 sound. Flege divided L2 speech into three types: similar phoneme which has a similar counterpart in L1, identical phoneme which has a totally same counterpart in L1, and new phoneme which has no counterpart in L2. SLM predicts that similar phoneme is the hardest type to acquire as L2 learners would incorrectly equal this sound to its similar counterpart in L1 and fail to establish new category for this sound. The second type is easy to master as L2 learners needn't to establish new category. Further, the third type is also relatively easy to acquire for new phoneme is robust to learners which would attract L2 learners' noticing and lead them to establish new category (Flege, 1995). The present study will examine the predictive and explanatory power of SLM by investigating the production of Mandarin fricatives by Cantonese speakers.

Mandarin has been an internationally popular language throughout the world with the developing of China. It's being learnt and spoken as a second language by a large population of learners. Consequently, there have been ample of studies of Mandarin learning. As Mandarin is a tonal language to which the tone plays a very important role in communication, previous research on Mandarin phonology in SLA domain narrowly focused on suprasegmental acquisition, to be more specific, tonal acquisition by learners from non-tonal language, like English, or language with different tonal system, like Cantonese (Gandour, 1983; Hallé *et al.*, 2004; Hao, 2018). The acquisition of Mandarin segments by learners from other Chinese dialects or other languages remains recent and scarce. Actually, the segments in Mandarin mean the same as the five tones, for inaccurate production or perception of Mandarin vowel or consonants would exert strong influence on the intelligibility and comprehensibility of one's speech. Thus L2 research on Mandarin segments is urgently needed.

Furthermore, Chinese has many dialects and most Chinese are born in a dialect-speaking speech, suggesting that standard Mandarin may be learnt as a second language for these people. Cantonese, as one primary dialect of Chinese, is spoken in Hong Kong, Macau, Guangdong and other neighboring southern regions. It's heard in nationwide and even abroad, such as in Sydney and Toronto. Due to its relatively pervasiveness, there has been

considerable amount of L2 research on Cantonese L1 learners, yet mainly focused on the acquisition of English speech as well as the perception and production of Mandarin tone. To our best knowledge, little study so far investigated the production of Mandarin segments by late Cantonese-Mandarin bilinguals. Therefore, the present study aims to fill such a literature gap by examining late Cantonese-Mandarin bilinguals' production of Mandarin fricatives. Fricatives are the largest consonant set in Mandarin in terms of articulatory manner, and an indispensible part of Mandarin segments acquisition. However, the amount of research relevant mismatches its importance. That's the very reason that the present study chose Mandarin voiceless fricatives as the target structure.

## 1.1. Mandarin Fricatives

In Mandarin, fricatives constitute a relatively large consonant set in terms of articulatory place. There are five vioceless fricatives, labiodental /f/, alveolar /s/, post-alveolar /ʃ/, palatal-alveolar /ɕ/, and velar /x/, and one voiced fricative, retroflex /ʐ/ in Mandarin. The six fricatives can be sub-divided into two types: sibilants /s, ʃ, ɕ, ʐ/ characterized by a concentration of energy in spectrum resulting from an obstacle inside the vocal tract, and non-sibilants /f, x/ characterized by a broad distribution of energy without airstream being obstacled (Shadle, 1990). Therefore, the sibilants are also called "obstacle fricatives" while the non-sibilants are called "wall fricatives" (Shadle, 1990).

## 1.2. Cantonese Fricatives

Different from Mandarin fricative system, Cantonese fricative system is relatively sparse, with only three fricatives, the labiodental /f/, the alveolar /s/ and the glottal /h/ (Zee, 1999). The labiodental /f/ and alveolar /s/ are identical to Mandarin /f/ and /s/ in terms of articulatory place with the reference to IPA (IPA, 1949). Yet it should be noted that, unlike Mandarin, the alveolar /s/ in Cantonese has an allophone /ʃ/ that appears before high front vowel /i/, which is termed as "palatalization"(Wong, 1941). The allophone /ʃ/ differs from /s/ in that it has a slightly backer articulation, similar to the post-alveolar /ʃ/ in Mandarin (Yuan, 1960). However, the glottal /h/ shows deviant from its counterparts in Mandarin in that its articulation is farther back. In addition, Mandarin palatal /ɕ/ has no similar or identical counterpart in Cantonese; hence the palatal-alveolar /ɕ/ is a new phoneme to Cantonese-Mandarin bilinguals.

## 1.3. Cross Language Influence on Fricative Production

Research on the production of fricative is relatively recent and insufficient as its requirement for recording environment and measurements. Flege (1995) researched the acquisition of English fricative contrast /θ/-/ ð/ by Italian speakers whose native language has no /θ/-/ ð/ contrast. The results showed that the /θ/-/ ð/ contrast was classified as equivalent to Italian /t/-/d/ respectively, suggesting a strong influence of L1 sound system on L2 learning. Besides, the influence of L1 depends on the distance between the L1 sound and the L2 sound.

Rau, Chang and Tarone explored the interlanguage variation of English voiceless interdental fricative produced by Chinese learners. This research took several influential factors including L1 background into consideration, such as immediate phonetic environment, lexical frequency and speech style. Results indicated that all the factors exerted influence on the participants' performance and lexical frequency slightly facilitated the production of the target structure. Further, L1 interference was observed in this study as Chinese learners rated and produced /s/-like sound as a substitution of English /θ/.

Chan (2010) investigated the acquisition of English consonant clusters (including fricative) by Cantonese ESL learners, aiming to test the explanatory ability of Markedness Differential Hypothesis and to explore the leaners' interlanguage phonological system. He found that there were phonotactic constraints of the learners' native language in the production. Jehma and Phoocharoensil (2014) explored the production of English fricatives and stops by Pattani-Malay speakers by comparing the production errors of Malay speakers and English natives. The research observed a negative transfer of L1 in L2 learning for Malay speakers substituted L2 new phoneme with close L1 counterparts, leading to inaccurate production.

It's not difficult to find that most of the studies on the production or acquisition of fricatives focused on English, other languages received much less attention. Peng (1993) investigated the interference between L1 and L2 by examining the production of Mandarin labiodental and velar fricatives and Taiwanese glottal /h/ by Taiwanese Amoy speakers. L1 interference to L2 was observed in this study, as L2 learners used the "equivalence classification" strategy. The extent of L1 interference depended on the learners' language proficiency of L2.

Wu (2011) made an investigation on the production of Mandarin consonants by Cantonese speakers from a pedagogical perspective. The researcher found that Cantonese speakers showed great deviants in producing many Mandarin consonants from native speakers. Many Cantonese speakers were accustomed to substitute Mandarin /ʃ/ which required tongue tip to roll back with Cantonese allophone /ʃ/ with tongue blade touching post-alveolar. The research also claimed that Cantonese speakers would incorrectly substitute Mandarin palatal /ɕ/ with /s/ due to the interference of L1. However, such an observation need to be verified as the research didn't provide detailed statistics. According to SLM, Mandarin /ɕ/ should be robust to Cantonese speakers as it is a new phoneme for them and easy to attract their attention.

To our best knowledge, few studies to date have investigated the production of Mandarin voiceless fricatives by L2 learners. The present study mainly focuses on this issue by examining the production of Mandarin voiceless sibilants /s, ʃ, ɕ/ by late Cantonese-Mandarin bilinguals , taking L1 interference and gender effect into consideration and making scientific acoustic analysis of two acoustic cues, spectral peak location of the target

structure and F2 onset of the following vowel. Basing on such research purposes, the present study forms three research questions:

1. Is there any significant gender effect in the production of Mandarin fricatives by both Cantonese speakers and Mandarin speakers?
2. What are the differences in the acoustic cues of the productions between Cantonese and Mandarin speakers?
3. Does the differences in acoustic cues relate to L1 interference?

Some relevant studies observed gender difference in the production of fricatives and other segments or suprasegmental features as female pays more attention to their articulation than male (Fox and Nissen, 2005); (Jin, 2015). Hence, the current study predicts a gender differences in voiceless fricatives between two groups.

It has been stated that there are differences between Mandarin and Cantonese fricative system. SLM predicts that new phoneme and identical phoneme are easy to learn whereas similar phoneme is hard to learn. /s/, an identical sound in Cantonese, and /ɕ/, a new sound, are predicted to be easily acquired and have no acoustic difference between two groups. However, /ʂ/ is considered as a similar sound, hence it's predicted to show deviants from native speakers.

# 2. Methodology

## 2.1. Participants

The participants in present study are divided into two groups: experimental group and control group. The experimental group consists of 10 late Cantonese-Mandarin bilinguals within which the number of male and female is counterbalanced. The participants ranged the age from 24-28 years. They were born and grown up in Cantonese-speaking community, never staying in other Mandarin-speaking community for more than six month. Their onset age of learning Mandarin ranged from 23-26 years. Their average frequency of speaking Cantonese in daily life amounts to 91%.

On the other hand, the control group consists of 10 Mandarin speakers which have equal number of male and female. The participants ranged the age from 23-30 years. They were born and grow up in Northern China and now study or work in Changsha. All of them got more than 86 score in National Standard Mandarin Examination. Their average frequency of speaking Mandarin amounts to 100%. No participant is reported to have language impairment or hearing disorder. The research was approved by human research ethics committee at Hunan University, and the recording process was approved by every participant.

## 2.2. Materials and Procedure

The stimuli in the present study consist of six disyllabic Mandarin words, *sijin*, *siji*, *shige*, *shigong*, *xiguang*, *xibian*, which contains the target voiceless sibilants /s ʂ ɕ/ on the first syllable. Due to phonological constraints in Mandarin, this study unifies the tone of each syllable which is combined with only a high level tone (tone 1). All the six words are familiar to both groups.

The participants were asked to fill a language background questionnaire, then, they entered the practice trial before formal experiment in order to familiarize the stimuli. The familiarization stage lasted for about 6 minutes. After that, the participants entered the formal experiment. The target stimuli were displayed on the computer screen one by one with their pinyin and meaning, and repeated for three times in the same displaying order. The participants were asked to read aloud the word in the screen by using a carries phrase " zhe shi ____" (This is _____). The displaying order of the six words was counterbalanced between two groups in order to avoid the influence of the displaying order. The recording was carried in a quiet room by a high quality microphone (Takstar 5500) and a computer (Acer Aspire V5). The tokens were recorded with a sampling rate of 22.05 kHz and 16-bit quantization.

## 2.3. Acoustic Measurement

The acoustic cues were measured and analyzed by Praat 6.0 (Boersma and Weenink, 2016). Firstly, Praat was used for segmentation and labeling. The segmentation of frication started from the point where energy concentration appeared and ended with the point before the first pulse or the first periodic pitch. The offset of the fricative was labeled as the onset of the following vowel, and the offset of the vowel was segmented to the last pulse in the spectrogram.

The present study mainly examined two acoustic cues: spectral peak location and F2 onset, for many studies have confirmed that these two cues were two distinctive features of voiceless fricatives (Jongman *et al.*, 2000; Lee S. I., 2011). The spectral peak was calculated in LPC curve of the midpoint of the frication. It could reflect the concentration of energy in the frication. Generally speaking, the descending rank of spectral peak value of the three fricatives should be /s ɕ ʂ/. The F2 onset was calculated in the beginning point of the vowel. Previous studies indicated that F2 onset of the following vowel could imply some articulatory information of the fricatives (Lee C. Y. *et al.*, 2014; Li and Munson, 2016).

The statistical analysis was done in SPSS 22.0 by adopting General Linear Model repeated measure ANOVA with the two acoustic cues as dependent variables, language background and gender as between-subject variables and articulatory place as within-subject variable. All post hoc tests (SIDAK) were performed to compare the differences in interaction between articulatory place, language background and gender with cirtical p value of 0.05.

# 3. Results

## 3.1. Spectral Peak Location

In this study, spectral peak location (hereafter, SPL) was considered as an important feature of the three voiceless sibilant fricatives. As it was shown in Figure 1 and Figure 2, language background and gender exerted influence on participants' performance in terms of SPL.

The results of the analysis of spectral peak value showed that there was significant main effect of articulatory place [F(2,32)=206.355, p<0.001]. The mean spectral peak value of the three target fricatives (/s ʂ ɕ/) were 5525, 4092 and 5333 respectively.

**Figure-1.** Spectral peak of Mandarin voiceless sibilant fricatives /s ʂ ɕ/ of late Cantonese-Mandarin bilinguals and Mandarin speakers

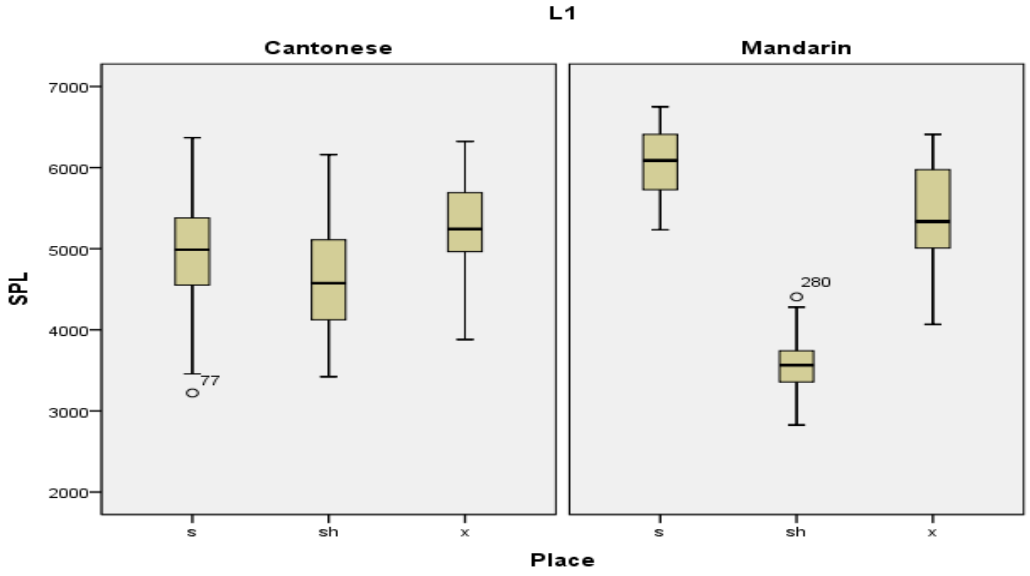
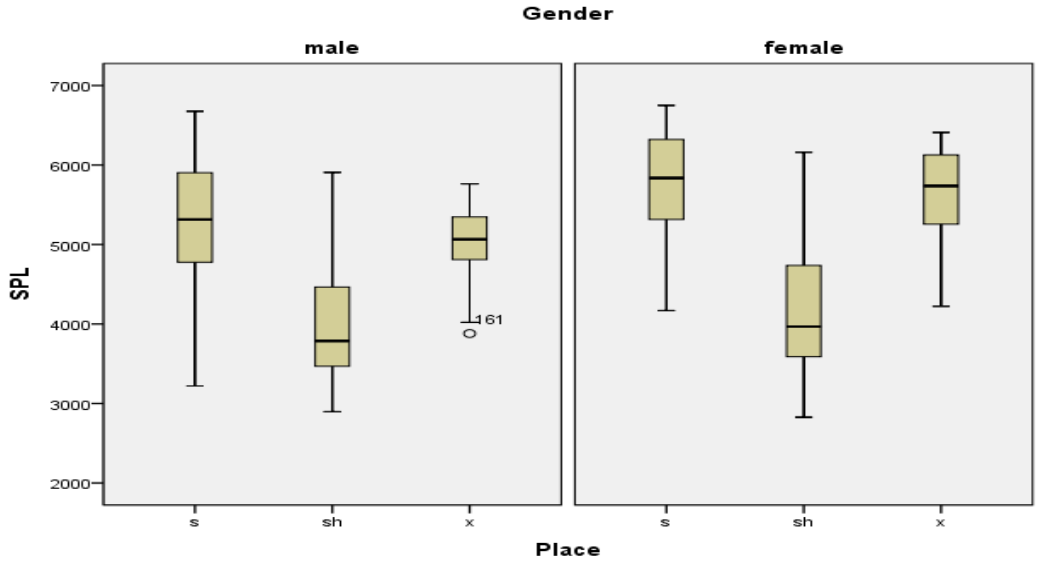



**Figure-2.** Spectral peak of Mandarin voiceless sibilant fricatives /s ʂ ɕ/ of male and female participants




Post hoc test indicated that there were differences among all the three fricatives. The analysis also reported significant main effect of gender [F(1,16)=20.021, p<0.001], yet no significant main effect was found of language background [F(1,16)=0.374, p=0.549]. However, there was significant interaction between articulatory place and language background [F(2,34)=101.833,p<0.001]. Simple effect analysis was conducted to examine which pair of fricatives the two groups differ in. The results suggested that Cantonese-Mandarin bilinguals and Mandarin natives produce different spectral peak values in fricative /s/ and /ʂ/ (for /s/, p<0.001; for /ʂ/, p<0.001) respectively, but no significant difference was reported for /ɕ/ (p=0.139). The mean spectral peak value of /s/ in Mandarin group was 6078, in accordance with the value obtained from previous study, much higher than that of Cantonese group, which indicated that Cantonese group produced Mandarin /s/ with much more backward tongue position. Contrary to /s/, the mean value of /ʂ/ for Mandarin group was much lower than that of Cantonese group, showing a L2-like production in Cantonese group.

Besides, significant interaction was also found for gender and place [F(2,34)=3.605, p<0.05], indicating significant differences between male and female in both groups in the three fricatives. Post hoc test found significant

differences in Mandarin /s/ and /ɕ/ ($p<0.001$) while no significant difference was found in /ʂ/ ($p=0.082$). For fricative /s/ and /ɕ/, female in both group produced higher and more standard mean spectral peak value than male. In addition, there was a significant three-way interaction for place*L1*Gender [$F(2,32)=4.483$, $p<0.05$]. Post hoc test implied that there were significant differences between Cantonese and Mandarin group for both male and female in /s/ and /ɕ/, whereas there was only significant difference between male and female in Cantonese group in /ʂ/ yet not in Mandarin group. To be more specific, /s/ and /ɕ/ produced by Mandarin and Cantonese female have higher mean spectral peak value, comparing with their gender counterparts. Differently, for /ʂ/, only Cantonese female produce much higher mean value than male. No such a significant difference between genders was found in Mandarin group.

## 3.2. F2 Onset

In the present study, spectral peak value was measured and the results were shown in Figure 3 and Figure 4. From these two figures, it's not difficult to find that there were large differences in mean F2 onset between late Cantonese-Mandarin bilinguals and Mandarin speakers, as well as between male and female in both groups.

The results of the analysis of F2 onset indicated a significant main effect of articulatory place [$F(2,32)=55.651$, $p<0.05$], suggesting that the articulatory place of the target fricatives exerted influences on F2 onset. A main significant effect of gender was also reported [$F(1,16)=31.985$, $p<0.05$], which implied that there were significant differences in F2 onset of all the three fricatives between male and female in general. Besides, a significant main effect was found for native language [$F(1,16)=9.897$, $p<0.05$], and there was a significant interaction between articulatory places and language background [$F(2,32)=173.086$, $P<0.05$].

**Figure-3.** Mean F2 onset of voiceless sibilant fricatives /s ʂ ɕ/ of late Cantonese-Mandarin bilinguals and Mandarin speakers

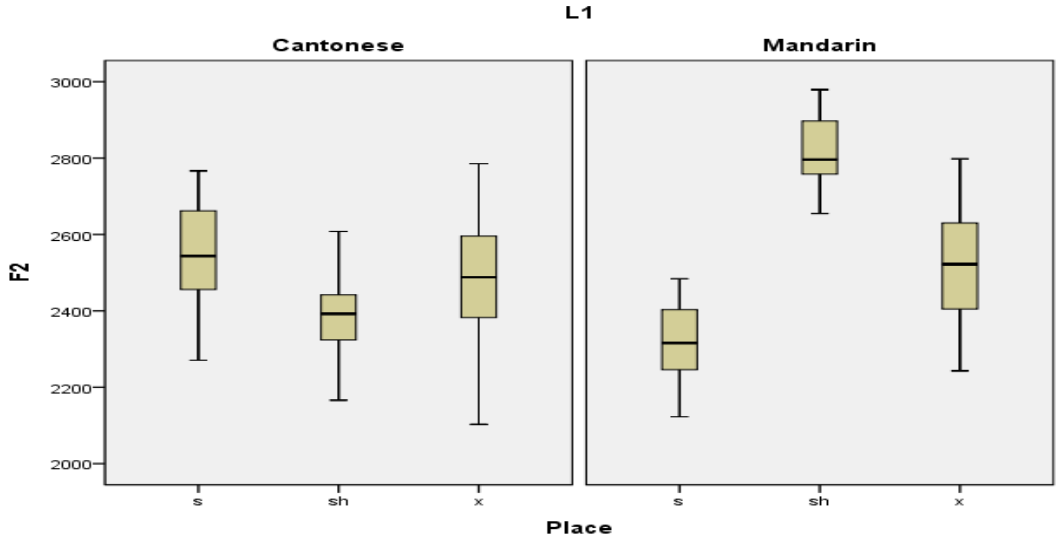
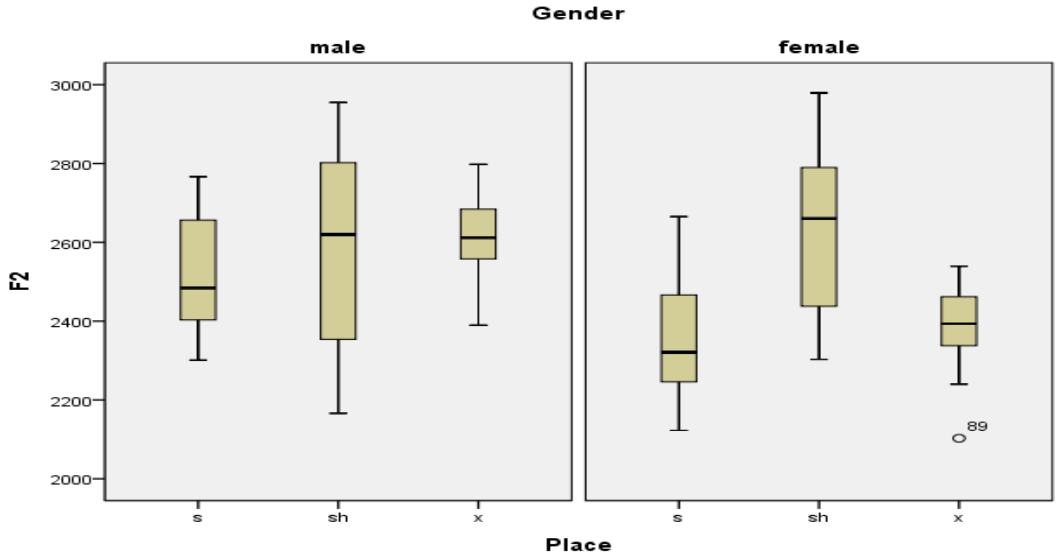



**Figure-4.** F2 onset of voiceless sibilant fricatives /s ʂ ɕ/ of male and female participants




Post hoc test indicated that there were significant differences in /s/ and /ʂ/ between the two groups yet no statistically significant difference was observed in /ɕ/ between the two groups. Specifically, the front vowel /i/ produced in /s/ context by Mandarin group had lower F2 onset than that by Cantonese group. To the contrast, the F2

onset of the front vowel /i/ in /ʂ/ context produced by Mandarin group was higher than that of Cantonese group. This result was in consistent with that found in spectral peak value.

Further, a significant interaction between articulatory place and gender was found [$F(2,32)=34.810$, $p<0.05$], indicating that female and male produced significantly different F2 onset for the target fricatives. Statistically significant differences were found in fricative /s/ and /ɕ/ between male and female in Post hoc test, but no significant difference was observed in /ʂ/. The mean F2 onset of /s/ and /x/ in female groups was lower than that in male groups. What's more, there was a significant three-way interaction among articulatory place, language background and gender [$F=(2,32)=9.213$, $p<0.05$]. Post hoc test observed significant differences in /s/ and /ɕ/ between male and female in both Mandarin and Cantonese groups, yet no statistically significant gender difference in /ʂ/ was found. For both groups, the mean F2 onset of /i/ in /s/ and /ɕ/ contexts obtained from female was lower than that from male. Some of the results of F2 onset were in a similar trend with that of spectral peak value.

## 4. Discussion

The present study investigated the production of Mandarin voiceless sibilant fricatives by late Cantonese-Mandarin bilinguals with the purposes to explore L1 interference and gender-related differences in the production, to test the predictive and explanatory power of SLM, and to provide some pedagogic enlightenment for Mandarin instruction for the dialect-speaking communities in China, especially for Cantonese-speaking communities. The participants were instructed to read aloud six disyllabic words of Mandarin which contained the target fricatives /s ʂ ɕ/. As previous studies have proved that spectral peak location and F2 onset were two distinct features of voiceless fricatives, the spectral peak location of each target fricative and F2 onset of the following vowel were measured in the present study. Three research questions were put forward and would be discussed in this section.

The first question the present study raised is about gender differences. There has been some research that discussed sex-related effect. Fox and Nissen (2005) found a significant gender effect in the production of English voiceless fricatives. Jin (2015) conducted a corpus-based study to investigate the sex-related differences on voiceless fricatives in American English. The results of acoustic analysis implied significant differences between male and female in most acoustic cues of voiceless non-sibilants. In the present study, significant gender differences in /s/ and /ʂ/ were observed. It could be explained in two perspectives. On one hand, the differences could be accounted by speech style. It have been suggested that female generally pay much more attention to their pronunciation than male no matter in daily life or in formal occasions. This can partially explain the lower and less standard spectral peak value of /s/ and /ʂ/ in male groups. On the other hand, the differences could be caused by physiological differences between male and female, as males generally have longer vocal tracts than females, which could lower the frequencies of sounds (Clark *et al.*, 2007; Davenport and Hannahs, 1998).

The gender differences in F2 onset resulted from the differences in articulatory place. It has been proved that the place where the constriction appears in the vocal tract decides F2 onset value and trend of the following vowel. With the place of articulation moving backward, F2 onset of its following vowel will increase. As it has been reported in Section 3 that male have a further backward place of articulation in /s/ and /ɕ/, the mean F2 onset in male groups is higher than female groups.

Then second research question concerns the influence of L1 on the productions of two groups. As it has been reviewed in Section 2 that L1 interference is an inevitable influential factor, the present study found partially same results with the previous studies. Flege (1995) conducted research on the production of English fricative contrast /θ/-/ ð/ by Italian speakers and found that this contrast was classified as equivalence to Italian /t/-/d/. This study observed similar "equivalence classification" phenomenon in Cantonese group as they produced Mandarin /ʂ/ with higher spectral peak value and lower F2 onset, suggesting that they had a further frontier articulatory place, approaching that of Mandarin /s/, which conformed to our prediction that Cantonese speakers would have difficult to achieve native-like production of /ʂ/. ANOVA analysis showed no significant differences in spectral peak value and F2 onset of /ɕ/ between the Cantonese and Mandarin group, implying that the Cantonese group managed to acquire the new phoneme /ɕ/ and build a new category for it, according with the prediction of SLM on the production of new L2 phoneme (Flege, 1995). However, this finding contradicts with the study conducted by Wu (2011) which claimed that Cantonese speakers could not produce Mandarin /ɕ/ accurately.

Strikingly, ANOVA analysis also indicated a statistically significant difference in spectral peak value and F2 onset of /s/ between the two language groups. According to SLM, identify L2 phoneme should be easy to learn. However, late Cantonese-Mandarin bilinguals produced Mandarin /s/ with lower spectral peak value and higher F2 onset, approaching to the value of Mandarin /ʂ/ produced by Cantonese speakers, implying that they have a place of articulation further back compared with Mandarin natives. The reason for such a phenomenon might be the close distance of Cantonese /s/ and Mandarin /ʂ/ in Mandarin phonology space. Hence Cantonese speakers are unable to discern the differences between /s/ and /ʂ/, and assimilate these two sounds into one overlapped phonology space.

Further, the present study aims to provide some pedagogic enlightenment for Mandarin teaching in dialect-speaking communities in China, especially Cantonese (or Yue dialect)-speaking communities. The findings of this study indicated that Cantonese speakers have difficult in producing Mandarin voiceless fricatives in a native-like manner, therefore, in practical teaching, the teacher should pay much attention to the Mandarin segment or suprasegment which has a similar counterpart in Cantonese. Besides, teacher should provide enough language inputs and create opportunities for language outputs for the learners, as both inputs and outputs are indispensable factors for successful L2 acquisition.

## 5. Conclusion

According to the result of comparative study of Mandarin voiceless sibilant fricatives /s ʂ ɕ/ by late Cantonese-Mandarin bilinguals and Mandarin speakers, late Cantonese-Mandarin bilinguals were able to achieve L1-like production of Mandarin /ɕ/, a new L2 sound, in terms of spectra peak and F2 onset. However, they failed to control native-like patterns of spectral peak location and F2 onset in Mandarin /s/ and /ʂ/, suggesting that they might combine these two sound into a single phonology space. The study also found significant gender-related differences in /s/ and /ɕ/ in the two language groups, resulting from the differences in speech style and physiologic structure between male and female.

To sum up, the findings of the present study over the phonological and phonetic realization of Mandarin voiceless sibilant fricatives by late Cantonese-Mandarin bilinguals and L1 Mandarin speakers imply a strong L1 interference in the late bilinguals' performance, which comforts to the predictions made by SLM. However, this study only measured two acoustic cues, spectral peak location and F2onset of the following vowel, which have been reported as two distinct features of voiceless fricatives. Further research is needed to discuss more acoustic cues. Besides, the present study failed to consider the influence of vowel context due to the phonological constraints of Mandarin, future study could combine real words and nonce words to explore the influence of vowel context.

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