Southeast Asia: A Multidisciplinary Journal, Vol 16, 2016, pp 89–102 © FASS, UBD

Alveolar and Post-alveolar Mergers in Brunei Mandarin

Shufang Xu

Universiti Brunei Darussalam

Abstract

Standard Mandarin has three alveolar sibilants /ts, tsʰ, s/ and three post-alveolar ones /ʈʂ, ʈʂʰ, ʂ/, but it has been suggested that they are merged in Brunei Mandarin. This study investigates the realisation of these two sets of sibilants in Brunei Mandarin. 20 Bruneians and 20 Chinese participated in recording a short text, the EWS passage, and three Bruneians additionally participated in a perceptual tests. Four spectral parameters were measured: Centre of Gravity (COG), Standard Deviation (SD), skewness, and kurtosis. Results show that the two classes of sibilants are merged into sounds intermediate between alveolar and post-alveolar sibilants, though these sounds are much closer to the alveolar sibilants. Hesitation in the discrimination tasks confirms that Brunei listeners have some difficulty in identifying the two classes auditorily.

Introduction

According to Catford (1988, p. 87), the alveolar ridge (as shown in Figure 1) can be considered to have two parts. One is the flat front part A, called the alveolar subzone, and the other is the convex back part B, called the post-alveolar subzone. Generally, consonants that are produced in the front part are called alveolar or dental-alveolar consonants, while those produced in the back part are called post-alveolar or retroflex consonants. Places such as A and B are the passive articulators, and the tip and blade of the tongue are the active articulators.

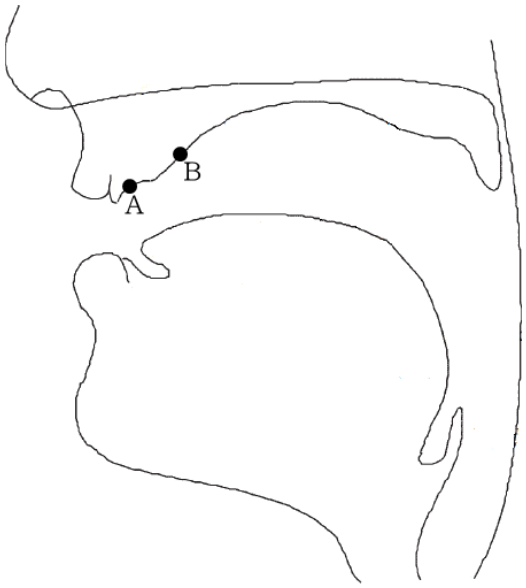

Figure 1. Alveolar (A) and post-alveolar (B) places (from Ladefoged & Disner, 2012, p. 116)

Standard Mandarin has two classes of contrastive sibilants. They are the three voiceless alveolar sibilants /ts, tsʰ, s/, represented as *z*, *c*, *s* in the Pinyin spelling system, and the three voiceless post-alveolar sibilants /ʈʂ, ʈʂʰ, ʂ/, represented as *zh*, *ch*, *sh* in Pinyin. We might note that the 'h' in the digraphs *zh*, *ch*, *sh* is used to show a post-alveolar place of articulation. Just as their names imply, the difference between these two classes can be captured in terms of

their places of articulation. For alveolar sibilants, the active articulator creates a constriction against the alveolar ridge, while for post-alveolar sibilants, the active articulator creates a constriction against the back part of the alveolar ridge, which is near the hard palate.

Figure 2 and 3 show the differences in the location of the energy in spectrograms between a alveolar sibilant and a post-alveolar sibilant. The frequency range in the spectrograms is from 0 to 15000 Hz. The main range of energy is marked by a bold square in the spectrograms, and the two classes of sibilants are clearly distinct from each other. It can be seen that the alveolar sibilants, which are high-pitched and intense, are characterised by greater amounts of energy at higher frequencies, while the post-alveolar sibilants are characterised by substantial amounts of energy at lower frequencies. For [s], much of the energy is above 6000 Hz, while for [ʂ], most of the energy is below 5000 Hz. We might expect, therefore, that the Center of Gravity (COG) of the spectrum can be used to identify the sounds acoustically. Figure 2 shows *sì* [sz] 四 as in *sì gè* [sz kɤ] 四个 ('four'), and Figure 3 shows *shǐ* [ʂz] 使 as in *shǐ jìn* [ʂz tɕin] 使劲 ('make every effort'), produced by speakers from China.

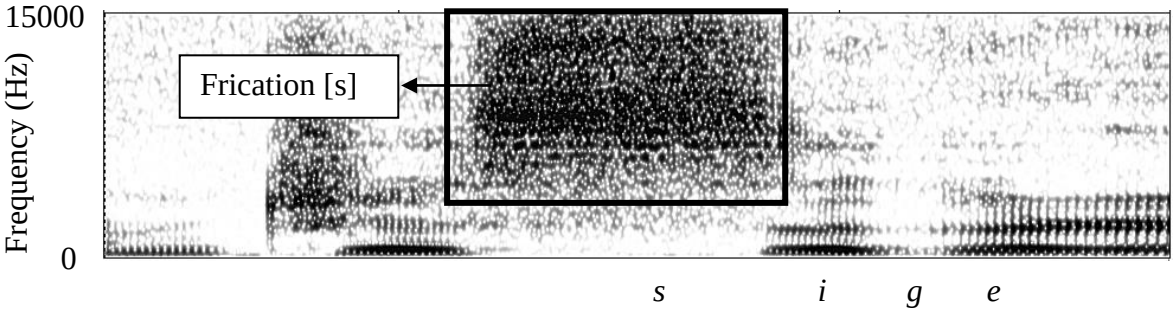

Figure 2. Spectrogram for the utterance *sì* by CF2

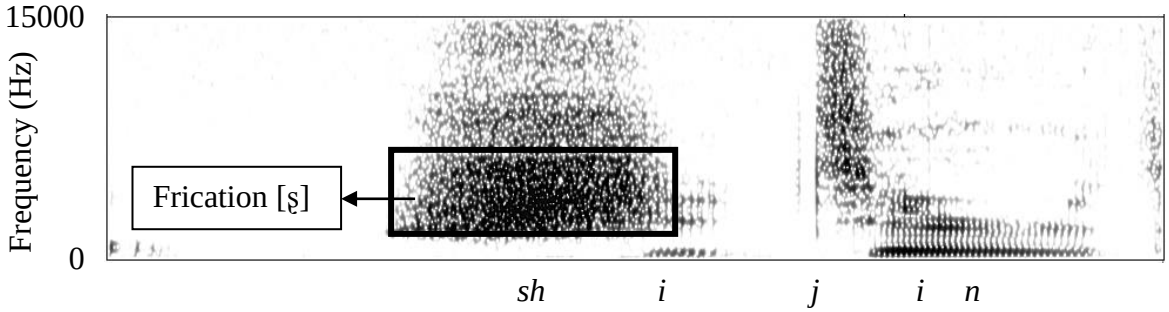

Figure 3. Spectrogram for the utterance *shǐ* by CF2

Among the six sibilants, /ts, tsʰ, ʈʂ, ʈʂʰ/ are affricates, while /s, ʂ/ are fricatives. Affricates are actually a combination of a stop closure and frication produced at the same place of articulation (Fujimura & Erickson, 1997, p. 77; Ashby, 2011, p. 61), so we expect that the alveolar and post-alveolar affricates can be differentiated by means of COG during the frication.

The aim of the current study is to provide a detailed acoustic characterisation of alveolar and post-alveolar sibilants in Brunei Mandarin by comparing them with those in Standard Mandarin. This study tries to answer the following questions:

1. Are alveolar sibilants differentiated from post-alveolar sibilants in Brunei Mandarin?
2. If they are merged, are they pronounced as alveolar, post-alveolar, or something in-between?
3. Can listeners in Brunei differentiate between these two classes?

Articulation

According to the traditional phonetic literature on Standard Madanrin, /ʈʂ, ʈʂʰ, ʂ/ are classified as retroflex sibilants (Chao, 1948, 1968; Lin, 1989; Laver, 1994; Duanmu, 2007). However, studies by Ladefoged and Wu (1984), Lee (1999) and Proctor, Li, Zhu, Goldstein and Narayanan (2012) provide more phonetic information on the articulatory characteristics of these sibilants, showing that they might not in fact be retroflex. The X-ray study by Ladefoged and Wu (1984), the palatographic, linguagraphic and acoustical investigation by Lee (1999) and the real-time MRI study by Proctor, Li, Zhu, Goldstein and Narayanan (2012) all find that the production of /ʂ/ involves no curling up or bending backwards of the tip of the tongue. Instead, /ʂ/ is produced with a flat tongue shape and a small sublingual cavity. Ladefoged and Maddieson (1986) also acknowledge that the retroflex fricatives in Standard Mandarin are very different from traditional retroflex fricatives such as the ones in Tamil and Hindi. The palatograms and linguograms in Lee (1999, p. 413) further suggest that it would be more accurate to classify /ts, tsʰ, s/ as dental-alveolar sibilants and /ʈʂ, ʈʂʰ, ʂ/ as post-alveolar sibilants. The lingual postures in Proctor, Li, Zhu, Goldstein and Narayanan (2012) also reveal that /s/ is produced with the tip of the tongue touching the post-dental passive articulator, while /ʂ/ is produced with a more laminal coronal gesture, and the exact place of articulation for /ʂ/ ranges from alveolar to palatal. Actually, the post-alveolar area is a general classification that includes many sub-categories such as palatal-alveolar, alveolopalatal and retroflex (Li, 2008, p. 11). However, the inconsistency of the place of articulation for these sibilants is probably because of the limited number of subjects in the studies above. Ladefoged and Wu (1984) only investigate three Beijing speakers, and Lee (1999) and Proctor, Li, Zhu, Goldstein and Narayanan (2012) only look at four native speakers of Standard Mandarin. In the current study, /ts, tsʰ, s/ and /ʈʂ, ʈʂʰ, ʂ/ are referred to as alveolar and post-alveolar sibilants respectively.

According to Keating (1991), the place of articulation for sibilants not only involves the tongue place and tongue posture, but it also involves secondary features such as lip rounding. However, the alveolar and post-alveolar sibilants mainly contrast as a result of the constriction in the oral cavity. More specifically, the X-ray tracing and X-ray photographs in Ladefoged and Wu (1984) show that there are slight differences in the place of articulation in the production of /s/ for their three Beijing speakers. Although they all raise the tip of the tongue to form a constriction at or near the teeth, the exact place of articulation of /s/ varies from one speaker to another. For speaker A, it is at the teeth; for speaker B, it is behind the teeth; and for speaker C, it is at the front part of the alveolar ridge. On the other hand, the place of articulation in the production of /ʂ/ is more consistent than /s/. All the three speakers produce /ʂ/ with the upper surface of the tip of the tongue being around the center of the alveolar ridge (Ladefoged & Wu, 1984, p. 271). Although the place of articulation of /ʂ/ is not exactly the post-alveolar region, alveolar sibilants are formed further forward than post-alveolar sibilants and these two classes generally maintain their contrasts in Standard Mandarin (Ladefoged & Wu, 1984).

In Taiwan Mandarin, a merger between alveolar and post-alveolar sibilants has been observed over the past few decades, as the pronunciation of Taiwan Mandarin is substantially influenced by Southern Min. It is reported that the post-alveolar sibilants are absent in Taiwan Mandarin, and they are replaced by their alveolar counterparts (Kubler, 1985). However, not all Taiwan speakers exhibit this merger. It is suggested that this merger is associated with a high frequency of using Southern Min (Chuang & Fon, 2010), and people living in the south part of Taiwan tend to have more evidence of this merger than those living in the north, as the frequency of use of Southern Min decreases from the south to the north in Taiwan. It is probably due to the fact that there are only three voiceless alveolar sibilants /ts, tsʰ, s/ and one voiced alveolar sibilant /z/ but no post-alveolar sibilants in Southern Min (Chung, 1996, p.

12). Moreover, Chuang and Fon (2010) claim that this merger also correlates with gender. In their investigation with eight Taiwan speakers (four females and four males), men show more incidences of merger than women.

Acoustic Properties

Compared with the variability of articulatory gestures in producing the sibilants, the acoustic parameters are relatively stable (Stevens, 1997, p. 463), illustrating that the same sounds can be pronounced in different ways. In comparing the alveolar and post-alveolar sibilants, the affricates and fricatives can be measured using the same methods as they both share a fricative part, and this frication is characterised by turbulent noise in the spectrograms. The different spectral shapes between alveolar and post-alveolar sibilants lie in the fact that they have a different size and shape of the oral cavity in front of the constriction. However, compared with labiodental and dental fricatives, alveolar and post-alveolar fricatives have more well-defined, distinct spectral shapes because of their longer anterior cavity (Jongman, Wayland & Wong, 2000, p. 1253). Specifically, post-alveolar fricatives have a longer anterior cavity than alveolar fricatives resulting in lower spectral peaks. For example, in English, the turbulent noise for /s/ appears in high frequency regions, around the range of the fourth and higher formants (Fujimura & Erickson, 1997, p. 76) and its major frequency peak is between 3500 to 5000 Hz (Behrens & Blumstein, 1988). However, the spectrum of the frication noise in the alveolar /s/ in Standard Mandarin can reach a peak in the range of fifth or sixth formants (Keyser & Stevens, 2006, p. 49). In fact, it is reported that most energy for alveolar fricatives is located above 4000 Hz (Chang, 2012, p. 20). For its counterpart /ʂ/, the peak of the frication noise is between the second and third formants (Keyser & Stevens， 2006, p. 49), so much of the energy is below 3000 Hz.

Retroflex approximants have a relatively stable acoustic cue: a lower F3 or a dipping F3. However, the post-alveolar sibilants are not vowels or sonorants, so they do not have formant structures. In addition, they are not retroflexes in a real sense (Ladefoged & Wu, 1984). Therefore, measurement of F3 is not feasible.

The acoustic study by Svantesson (1986) reports that alveolar sibilants and post-alveolar sibilants in Standard Mandarin can be distinguished by center of gravity (COG), dispersion, and mean intensity level, especially that alveolar sibilants have higher COG than their post-alveolar counterparts. As the COG of post-alveolar sibilants decreases, the overall intensity is higher than that of alveolar sibilants (Svantesson, 1986, p. 58).

Center of gravity is a measure of the location of the average frequency in a spectrum. It is a general purpose articulatory measure (Tabain, 2013, p. 39) and it reflects details concerning the front cavity size and constriction shape (Nittrouer, Studdert-Kennedy & McGowan, 1989, p. 122). For example, a higher COG corresponds to a more forward place of articulation (van't Veer, 2013, p. 35). It is reported that COG is reliable to distinguish /s/ and /ʃ/ in English (Nittrouer, Studdert-Kennedy & McGowan, 1989). The Standard Deviation (SD) measures how much the frequencies deviate from the COG and is used as a measure of how broadly the frequencies are spread in the spectrum (McDonough, 2003, p. 134).

Skewness and kurtosis both provide summary information about the shape of a distribution (DeCarlo, 1997, p. 296). Skewness is a measure of the shape of the spectrum on either side of the COG, and it indicates a distribution's asymmetry (Watt, 2013, p. 96). Usually, a skewness of zero indicates a symmetrical distribution around the mean. According to Jongman, Wayland and Wong (2000, p. 1253), skewness is related to spectral tilt, which is the overall slant of the energy distribution. Positive skewness suggests a negative tilt with a concentration of energy in the lower frequencies, while negative skewness is associated with a positive tilt and a predominance of energy in the higher frequencies.

Kurtosis indicates how far the shape of the spectrum deviates from a Gaussian (normal distribution) curve (Watt, 2013, p. 96), and it can reflect both tailedness and peakedness in the distribution (DeCarlo, 1997, p. 294). Positive kurtosis values indicate high peakedness, while negative values indicate relatively light tails and a flat distribution. Therefore, positive kurtosis suggests a clearly defined spectrum with a well-resolved peak, while negative kurtosis indicates a relative flat spectrum without a clearly defined peak (Jongman, Wayland & Wong, 2000, p. 1253).

In sum, these measures are able to classify sibilants because of their ability to summarise the concentration, tilt and peakedness of the energy distribution (Forrest, Weismer, Milenkovic & Dougall, 1988, p. 116). In recent years, these spectral moments have been applied effectively to the examination of affricates and fricatives in different languages (e.g. for English by Jongman, Wayland & Wong, 2000; Jones & McDougall, 2009; Weirich & Simpson, 2015; for German by Jannedy, Weirich & Helmeke, 2015; and for Navajo by Mcdonough, 2003). Therefore, the spectral moments suffice to distinguish acoustically between alveolar and post-alveolar sibilants.

Acoustic Study

Although it has been suggested that there is a tendency for merging between alveolar and post-alveolar sibilants in Brunei Mandarin, no instrumental or perceptual studies concerning this impressionistic observation have been conducted so far. Since human judgments are sometimes subject to error, it is suggested that instrumental analysis go hand in hand with auditory judgments (Heselwood, 2013). The current study uses acoustic analysis together with perceptual judgments.

Over the years, the fable *the North Wind and the Sun* (the NWS passage) (IPA 1999, p. 39) has been used as an illustrative passage by the International Phonetic Association (IPA) and it has been translated into a wide range of languages to illustrate their pronunciation. However, to cater for the description of a particular language or dialect, changes to the text are advisable as it is "clearly inappropriate for some cultures and may be replaced in whole or in part to make it suitable for the particular language or dialect" (Ladefoged & Johnson, 2011, p. 297). So in this study, the NWS text was revised.

Problems with the Chinese version of the NWS passage

The Standard Chinese version of the NWS passage used by Lee and Zee (2003) has shortcomings, such as the absence of some sounds (Deterding, 2006, p. 190). Furthermore, some of the words are difficult for non-Beijing speakers, so the passage is not ideal for the description of varieties of Mandarin, especially for speakers who are not from Beijing.

One vowel and two consonants of Mandarin are absent from the NWS passage used by Lee and Zee (2003). They are the front rounded vowel /y/, the dental affricate /ts^{h}/ and the alveolo-palatal affricate /tɕ^{h}/. Standard Mandarin has five vowel phonemes, including /y/, which can be found in many common words in Mandarin such as *nǚ* [ny] (女 'female') and *yú* [y] (鱼 'fish'). /ts^{h}/ and /tɕ^{h}/ are also two common consonants in Mandarin. Without these sounds, there cannot be a complete description of the sound inventory of Standard Mandarin.

In addition, the NWS passage in Mandarin is not complete in terms of all the (G)V(X) finals. In Standard Mandarin, there are 34 possible (G)V(X) finals (Duanmu, 2007, p. 67). The NWS passage in Mandarin has only 23 (G)V(X) forms, the missing forms being /an, je, juŋ, ɥy, ɥan, ɥyn, wɑ, wɑi, waŋ, wəŋ, uŋ/. Some of these absent forms are actually rather common in Mandarin. For example, *ān* [an] (安 'safe'), *yě* [je] (也 'also') and *yú* [ɥy] (鱼 'fish') are high frequency words. Only /wəŋ/ is less common in Mandarin, and this will be discussed later.

Similar to the version of English, the NWS passage in Mandarin has high repetition of lexical items. The passage has a total of 161 characters, with only 80 different characters and 81 repeated lexical items, rendering the repetition rate 50.3%. The degree of repetition partly explains the absence of some sounds and the lack of 11 (G)V(X) finals. Repetition has its advantages and disadvantages. It allows researchers to evaluate the degree of variation by a speaker, and it reveals variation in the pronunciation of a word in different phonetic environments (Deterding, 2006, p. 190). However, high repetition rate limits the occurrence of certain segments.

Another problem with the NWS passage in Mandarin as used by Lee and Zee (2003) is the level of difficulty of some words that might affect speakers' performance. It includes some words that are only used in Beijing Mandarin, and people whose first language is not Mandarin might find it hard to read these words. For example, *páozi* (袍子 'cloak'), *mǎozúlejìnr* (卯足了劲儿 'spare no effort'), *dàomòliǎor* (到末了儿 'finally'), and *méizhé* (没辙 'run out of solutions') are rare words outside of Beijing. Many people in Brunei whose heritage languages are southern dialects have not encountered these words. Therefore, it would be rather difficult for Brunei speakers to understand the passage, let alone to read it fluently.

The improved EWS passage

A new passage titled as *the East Wind and the Sun* (the EWS text) is used in this study. The *North Wind* is changed to the *East Wind* to allow comparison of the vowel in *dōng* (东 'east') and *fēng* (风 'wind'), as some speakers have the same vowels in those two syllables, even though in Standard Mandarin they are different: [u] vs. [ə]. Transcription and translation can be found in Appendix 1.

东风和太阳

一天中午，白云听见东风和太阳在那儿你争我吵，都说自己的本事大。这时，从森林的草地里来了一个老公公，一个妈妈和她的女儿，还有一个小王子，全身都穿着破旧的衣服。于是，白云说，只要谁能让这四个人把衣服脱下，就算谁的本事大。然后，东风就张开口，使劲儿地吹。但是，它刮得越用力，他们四个就把衣服拉得更紧。最后，东风累了，也没什么办法了。一会儿，轮到太阳了，他们一看见阳光，热得快快把衣服脱了下来。所以，东风不得不同意，还是太阳比较强。

Speakers

20 speakers of Brunei Mandarin (10 female and 10 male) and 20 speakers of Mandarin in Beijing (10 female and 10 male) were recorded reading the EWS passage. At the time of the study, the Brunei speakers had a mean age of 21 years, ranging from 19 to 23 years, while the Beijing speakers had a mean age of 24 years, ranging from 20 to 30 years. Of the 20 Brunei speakers, 12 were from Universiti Brunei Darussalam (UBD), seven were from Institut Teknologi Brunei (ITB), and one was from Kolej IGS Brunei Darussalam (IGS), a private tertiary institution in Brunei. The 20 Beijing speakers were students all from Beijing Language and Culture University (BLCU). Apart from two speakers from Beijing, 18 were from different provinces, i.e. Inner Mongolia, Heilongjiang, Jilin, Liaoning, Shandong, Henan, Hebei, Hubei, Guizhou, Zhejiang. They all speak standard Mandarin with little accent from their home dialect. In this study, we will label the Brunei females, Brunei males, China females and China males as BF, BM, CF and CM respectively.

Methodology

In the present study, three tokens of alveolar sibilants and three tokens of post-alveolar sibilants were extracted from each recording of the EWS text (see Table 1).

Alveolar sibilants	**Post-alveolar sibilants**
zì *jǐ* [**tsz** tɕi] 自己 (‘self’)	***zhǐ*** *yào* [**ʈʂz̩** jau] 只要 (‘as long as’)
sì *gè* [**sz** kɤ] 四个 (‘four’)	*dàn* ***shì*** [tan **ʂz̩**] 但是 (‘but’)
sēn *lín* [**sən** lin] 森林 (‘forest’)	*quán* ***shēn*** [tɕʰɥan **ʂən**] 全身 (‘the whole body’)

Table 1. Tokens examined in the EWS test.

The first pair of syllables, *zì* and *zhǐ*, are not a true minimal pair, as they differ in tones as well as the consonants. The other two pairs of syllables, *sì* vs. *shì*, and *sēn* vs. *shēn* are minimal pairs. Since there are no minimal pairs of /tsʰ/ and /ʈʂʰ/ in the EWS text, this study only looks at /ts, s/ and /ʈʂ, ʂ/.

The frication part of each token was measured in Praat (Boersma & Weenink, 2015). Since the spectral characteristics remain relatively stable over the duration of the frication (Behrens & Blumstein, 1988), all measurements were taken at the midpoint of the frication with a Hamming window length of 0.025s. The four spectral parameters: COG, SD, skewness and kurtosis were calculated via spectral slices, and then the results for alveolar and post-alveolar sibilants were compared using independent-samples *t*-tests. In order to see to what extent alveolar sibilants contrast with post-alveolar sibilants in Brunei Mandarin and Standard Mandarin, scatter plots were made with SD against COG. SD versus COG was chosen because, unlike spectral tilt, SD is not correlated with COG. In addition, skewness and kurtosis have limited discriminating power to separate alveolar sibilants from post-alveolar sibilants across all speakers (Evers, Reetz & Lahiri, 2003, p. 366), and for the Beijing speakers, COG and SD had the best discrimination.

Results

Tables 2 and 3 show the mean values of the four spectral moments including an independent samples *t*-test to compare each of the spectral moments between alveolar and post-alveolar sibilants in Brunei Mandarin and Standard Mandarin.

The *t*-tests reflect the bigger differentiation between alveolar and post-alveolar sibilants by Beijing speakers than by Brunei speakers. As seen in Table 2, the averaged values of the four spectral moments between the two classes of sibilants for Brunei speakers are fairly close. The results for COG show that the energy concentration for alveolar and post-alveolar sibilants in Brunei Mandarin is similar, and the SD for the two classes of sibilants are almost identical. The skewness for the two classes are also quite close, with both below zero, indicating that they both have high energy peaks, and there is little difference between kurtosis in the two classes, with their average kurtosis values about 2.5, indicating a relatively high peakedness. None of the differences in the spectral moments reaches statistical significance, indicating that, overall, Brunei speakers do not make a contrast between alveolar and post-alveolar sibilants.

	Alveolar	Post-alveolar	*t*	*p*
COG	7064 (1676)	6539 (1578)	1.77	0.08
SD	2372 (626)	2341 (660)	0.26	0.80
Skewness	-0.26 (1.14)	-0.06 (1.12)	0.94	0.35
Kurtosis	2.68 (3.48)	2.46 (3.72)	0.33	0.74

Table 2. Mean values of the four spectral moments for Brunei speakers (standard deviation is in brackets)

	Alveolar	Post-alveolar	*t*	*p*
COG	7465 (1560)	3630 (450)	18.30	< 0.001***
SD	3344 (868)	1665 (439)	13.36	< 0.001***
Skewness	-0.66 (0.74)	0.99 (0.81)	11.67	< 0.001***
Kurtosis	0.92 (2.26)	5.15 (4.40)	6.62	< 0.001***

Table 3. Mean values of the four spectral moments for Beijing speakers (standard deviation is in brackets)

By contrast, as shown in Table 3, the average values of the four spectral moments between the two classes of sibilants for Beijing speakers are far apart and their differences are all highly significant, indicating that alveolar sibilants are distinct from post-alveolar sibilants in Standard Mandarin. The average COG of alveolar sibilants is 7465 Hz, indicating high-frequency energy, while the average COG of post-alveolar sibilants is 3630 Hz, indicating much lower frequency energy. This suggests that the two classes of sibilants for Beijing speakers are consistent with the spectrograms of Figure 2 and 3. The different SD between the two classes of sibilants for Standard Mandarin for alveolar sibilants is twice as high as it is for post-alveolar sibilants, indicating that the dispersion of energy for alveolar sibilants is much broader than for post-alveolar sibilants. The average skewness for alveolar sibilants is -0.66, indicating a higher energy peak, while the average skewness for post-alveolar sibilants is 0.99, indicating a lower energy peak.

Using a scatter plot provides a visual description of the distribution of the two classes of sibilants. Plotting SD against COG as shown in Figure 4 and 5, it can be seen that alveolar and post-alveolar sibilants in Brunei Mandarin are merged together, with the COG of all the sibilants ranging from 4000 to 10000 Hz, while they are clearly separated in Standard Mandarin, with the COG of alveolar sibilants ranging from 5000 Hz to 10000 Hz, while the COG of post-alveolar sibilants range from 3000 Hz to 4000 Hz. The relatively high COG for the alveolar sibilants suggests that they are more fronted. We might note that there are two outliers of alveolar sibilants in Figure 5. The COG of these two tokens of alveolar sibilants is within the range between 3000 Hz to 4000 Hz, and auditory judgment confirms that these two tokens are pronounced as post-alveolar consonants. One is *sēn* from CF1, who is from Henan Province, and the other is *zì* from CM2, who is from Shandong Province. Even though neither is from the southern areas of China, the two outliers might be regarded as tokens of hypercorrection in Standard Mandarin, using a post-alveolar sound when an alveolar sound is expected.

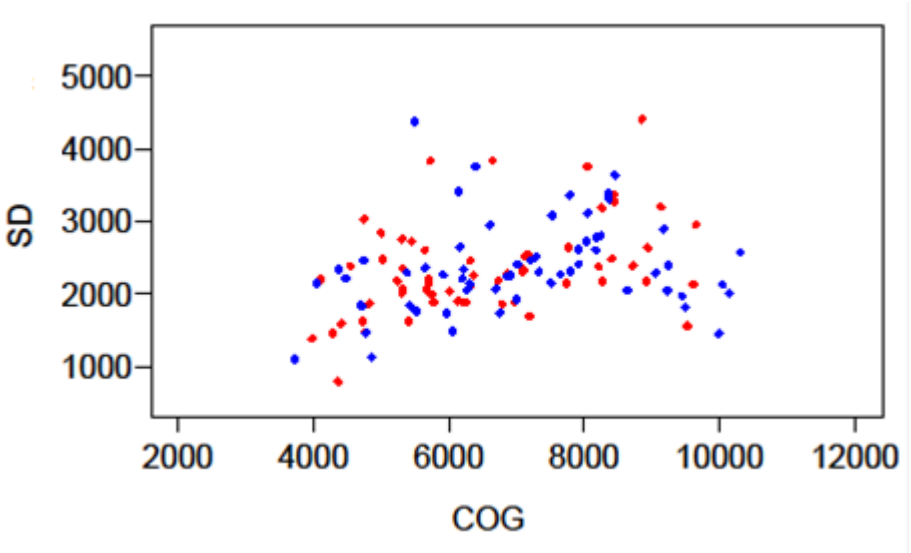

Figure 4. Scatter plot of SD against COG in Brunei Mandarin (red: post-alveolar sibilants; blue: alveolar sibilants)

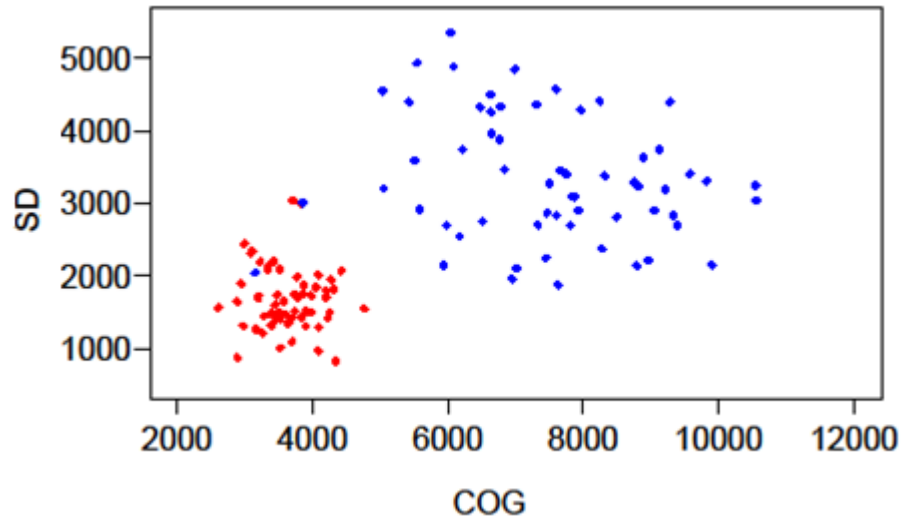

Figure 5. Scatter plot of SD against COG in the Beijing data (red: post-alveolar sibilants; blue: alveolar sibilants)

As mentioned above, SD measures the dispersion of energy. As seen in Figure 4, the values of SD for the Brunei data range from 900 to 4500 Hz, without any separation of alveolar and post-alveolar sibilants. In contrast, in the Beijing data, as shown in Figure 5, there is a clear separation between alveolar and post-alveolar sibilants in terms of Standard Deviation. The values of Standard Deviation for alveolar sibilants center between 2000 to 5000 Hz, indicating alveolar sibilants have much broader energy bands. However, most of the values of SD for post-alveolar sibilants are between 1000 to 2000 Hz, indicating a more compact energy.

In addition, the phonetic realisations of the two classes of sibilants are not simply shifted from one to the other in Brunei Mandarin. In other words, it is not that either class of sibilants replaces the other, even if it seems that post-alveolar sibilants tend to be pronounced as alveolar sibilants because they are produced rather forward. Unlike the absence of post-alveolar sibilants in Taiwan Mandarin (Kubler, 1985), the two merged classes of sibilants constitute sounds between alveolar and post-alveolar sibilants. Evidence can be found in Table 2 and 3. Specifically, the average values of COG in Brunei Mandarin lie between the

3630 Hz and 7465 Hz of Standard Mandarin for both alveolar and post-alveolar sibilants, though it should be admitted that the values for both alveolar and post-alveolar sibilants of the Brunei data are closer to the average COG of the alveolars than the post-alveolars in the Beijing data. Although the post-alveolar sibilants in Brunei Mandarin tend to be pronounced as alveolar sibilants, these alveolar sibilants are not the same as those in Standard Mandarin. Similarly, the SD for both sounds in Brunei Mandarin lies between the two SD values in Standard Mandarin, and the same is true for skewness and kurtosis. Therefore, it is more appropriate to say that the alveolar and post-alveolar sibilants in Brunei Mandarin are sounds that are intermediate between the alveolars and post-alveolars of the Beijing data.

Perceptual Study

As mentioned above, there are articulatory and acoustic differences between alveolar and post-alveolar sibilants of Standard Mandarin, but it remains unclear whether these differences are perceived by Brunei speakers. The purpose of the perceptual experiment is to test whether subjects can classify alveolar and post-alveolar sibilants auditorily.

Methodology

For the perceptual test, a discrimination task was conducted. Three subjects (BF1, BF6, BM1) were invited back to the perceptual experiment. They were asked to listen to 12 sentences recorded by the researcher and to identify the characters embedded in a carrier sentence. The data of alveolar and post-alveolar sibilants were two minimal pairs: *zǐ* 子 (‘son’) vs. *zhǐ* 纸 (‘paper’) and *sì* 四 (‘four’) vs. *shì* 是 (‘be’), which were imbedded in the carrier sentence: 请你把____再说一遍 (‘Please say____once again’) in randomised order. They had 12 options of characters to choose for each sentence (你, 发, 力, 鱼, 妈, 绿, 是, 女, 子, 姨, 纸, 四), and they were asked to circle the ones they heard. The full discrimination task is attached in Appendix 2.

Results

The accuracy rate was analysised for the discrimination task. Table 4 shows the accuracy rate for the two minimal pairs. Of the three subjects, only one subject (BF6) could identify all the alveolar and post-alveolar sibilants correctly. The other two subjects (BF1 and BM1) each failed to identify one character correctly. Specifically, BF1 mistakenly identified *zǐ* 子 (‘son’) as *zhǐ* 纸 (‘paper’), while BM1 mistakenly identified *zhǐ* 纸 (‘paper’) as *zǐ* 子 (‘son’).

Character	*zǐ* 子	*zhǐ* 纸	*sì* 四	*shì* 是
Accuracy rate	66.6%	66.6%	100%	100%

Table 4. Accuracy rate for the two minimal pairs

In addition, all three subjects displayed hesitation while identifying the four characters, as they paused longer than identifying other characters in the discrimination task. This suggests that they had some difficulties differentiating the two classes of sibilants auditorily.

Conclusion

In this study, it was found that in Brunei Mandarin, alveolar and post-alveolar sibilants do not differ in their place of articulation, and they are merged together into a sound between alveolar and post-alveolar sibilants, though this sound is closer to alveolar sibilants. In

Standard Mandarin, alveolar and post-alveolar sibilants are almost all separated by plotting COG against SD, but this plot shows that the sounds are merged in Brunei Mandarin.

References

Ashby, P. (2011). *Understanding phonetics*. UK: Hodder Education.

Behrens, S. J., & Blumstein, S. E. (1988). Acoustic characteristics of English voiceless fricatives. *Journal of Phonetics, 16*(3), 295–298.

Boersma, P., & Weenink, D. (2015). Praat: Doing phonetics by computer [computer software]. Retrieved on 12 July 2015, from <http://www.fon.hum.uva.nl/praat/>

Catford, C. C. (1988). *A practical introduction to phonetics*. Oxford: Clarendon Press.

Chang, Y. H. (2012). Variability in cross-dialectal production and perception of contrasting phonemes: The case of the alveolar-retroflex contrast in Beijing and Taiwan Mandarin. Doctoral dissertation, University of Illinois at Urbana-Champaign.

Chao, Y. R. (1948). *Mandarin primer*. Cambridge, Massachusetts: Harvard University Press.

Chuang, Y. Y., & Fon, J. (2010). The effect of prosodic prominence on the realization of voiceless dental and retroflex sibilants in Taiwan Mandarin spontaneous speech. In *Proceedings of the 5th International Conference on Speech Prosody*, Chicago, 11–14 May 2010, No. 100414.

Chung, R. (1996). The segmental phonology of Southern Min in Taiwan. Taipei: The Crane Publishing Co., Ltd.

DeCarlo, L. T. (1997). On the meaning of use of kurtosis. *Psychological Methods, 2*(3), 292–307.

Deterding, D. (2006). The North Wind versus a Wolf: Short texts for the description and measurement of English pronunciation. *Journal of the International Phonetic Association* 36(2), 187–196.

Duanmu, S. (2007). *The phonology of standard Chinese* (2nd ed.). Oxford: Oxford University Press.

Evers, V., Reetz, H., & Lahiri, A. (1998). Crosslinguistic acoustic categorisation of sibilants independent of phonological status. *Journal of Phonetics, 26*(4), 345–370.

Forrest, K., Weismer, G., Milenkovic, P., & Dougall R. N. (1988). Statistical analysis of word-initial voiceless obstruents: Preliminary data. *Journal of the Acoustic Society of America* 84(1), 115–123.

Fujimura O., & Erickson, D. (1997). Acoustic phonetics. In W. J. Hardcastle & J. Laver (Eds.), *The handbook of phonetic sciences* (pp. 65–115). Oxford: Blackwell Publishers.

Heselwood, B. (2013). *Phonetic transcription in theory and practice*. Edinburgh: Edinburgh University Press.

IPA (ed.). (1999). *Handbook of the International Phonetic Association*. Cambridge: Cambridge University Press.

Jannedy, S., Weirich, M., & Helmeke, L. (2015). Acoustic analyses of differences in [ç] and [ʃ] productions in Hood German. In *Proceedings of the 18th International Congress of Phonetic Sciences, ICPhS XVIII*. Glasgow, 10–14 August 2015.

Jones, M. J., & McDougall, K. (2009). The acoustic character of fricated /t/ in Australian English: A comparison with /s/ and /ʃ/. *Journal of the International Phonetic Association, 39*(3), 265–289.

Jongman, A., Wayland, R., & Wong, S. (2000). Acoustic characteristics of English fricatives. *Journal of the Acoustical Society of America, 108*(3), 1252–1263.

Keating, P. A. (1991). Coronal places of articulation. In C. Paradis & J. Prunet. (Eds.), *Phonetics and phonology 2: The special status of coronals. Internal and external evidence* (pp. 29–48). San Diego: Academic Press.

Keyser, S. J., & Stevens, K. N. (2006). Enhancement and overlap in the speech chain. *Language*, *82*(1), 33–63.

Kubler, C. C. (1985). The influence of Southern Min on the Mandarin of Taiwan. *Anthropological Linguistics*, *27*(2), 156–176.

Ladefoged, P., & Johnson, K. (2011). *A course in phonetics* (6th ed.). Boston: Wadsworth, Cengage Learning.

Ladefoged, P., & Maddieson, I. (1996). *The sounds of the world's languages*. Oxford: Blackwell Publishers.

Ladefoged, P., & Wu, Z. (1984). Places of articulation: An investigation of Pekingese fricatives and affricates. *Journal of Phonetics*, *12*, 267–278.

Laver, J. (1994). Principles of phonetics. Cambridge: Cambridge University Press.

Lee, W. S. (1999). An articulatory and acoustical analysis of the syllable-initial sibilants and approximants in Beijing Mandarin. In *Proceedings of the 14th International Congress of Phonetic Sciences ICPhS XIV* (pp. 413–416). San Francisco, 1–7 August 1999.

Lee, W. S., & Zee, E. (2003). Standard Chinese (Beijing). *Journal of the International Phonetic Association* 33(1), 109-112.

Li, F. (2008). The phonetic development of voiceless sibilant fricatives in English, Japanese and Mandarin Chinese. Doctoral dissertation, Ohio State University.

Lin, Y. H. (1989). The retroflex as a complex segment. *ESCOL*, *6*, 182–193.

McDonough, J. (2003). *The Navajo sound system*. Dordrecht: Kluwer Academic Publishers.

Nittrouer, S., Studdert-Kennedy, M., & McGowan, R. S. (1989). The emergence of phonetic segments: Evidence from the spectral structure of fricative-vowel syllables spoken by children and adults. *Journal of Speech and Hearing Research*, *32*(1), 120–132.

Proctor, M., Li, H. L., Zhu, Y., Goldstein, L., & Narayanan, S. (2012). Articulation of Mandarin sibilants: A multi-plane realtime MRI study. In *Proceedings of the 14th International Conference on Speech Science and Technology* (pp. 113–116). Sydney, 3–6 December 2012.

Stevens, K. N. (1997). Articulatory-acoustic-auditory relationships. In W. J. Hardcastle & J. Laver (Eds.), *The handbook of phonetic sciences* (pp. 462–506). Oxford: Blackwell Publishers Ltd.

Svantesson, J. O. (1986). Acoustic analysis of Chinese fricatives and affricates. *Journal of Chinese Linguistics*, *14*(1), 53–70.

Tabain, M. (2013). Research methods in speech production. In M. J. Jones & R. Knight (Eds.), *The Bloomsbury companion to phonetics* (pp. 39–56). London: Bloomsbury Academic.

van't Veer, M. (2013). On the place of rhotics: A case study on the acquisition of French /ʁ/. In L. Spreafico & A. Vietti (Eds.), *Rhotics: New data and perspectives* (pp. 23–40). Bozen-Bolzano University Press.

Watt, D. (2013). Research methods in speech acoustics. In M. J. Jones & R. Knight (Eds.), *The Bloomsbury companion to phonetics* (pp. 79–97). London: Bloomsbury.

Weirich, M., & Simpson, A. P. (2015). Gender-specific differences in sibilant contrast realisations in English. In *Proceedings of the 18th International Congress of Phonetic Sciences, ICPhS XVIII*. Glasgow, 10–14 August 2015.

Appendix 1: The EWS Text

东风和太阳

一天中午，白云听见东风和太阳在那儿你争我吵，都说自己的本事大。这时，从森林的草地里来了一个老公公，一个妈妈和她的女儿，还有一个小王子，全身都穿着破旧的衣服。于是，白云说，只要谁能让这四个人把衣服脱下，就算谁的本事大。然后，东风就张开口，使劲儿地吹。但是，它刮得越用力，他们四个就把衣服拉得更紧。最后，东风累了，也没什么办法了。一会儿，轮到太阳了，他们一看见阳光，热得快快把衣服脱了下来。所以，东风不得不同意，还是太阳比较强。

Transcription

tuŋ fəŋ xɤ tʰai jaŋ

ji tʰjan ʈʂuŋ wu | pai ɥin tʰjəŋ tɕjan tuŋ fəŋ xɤ tʰai jaŋ tsai naə̆ ni ʈʂəŋ wo ʈʂʰau | təu ʂwo tsz tɕi tɤ pən ʂʐ̩ tɑ | ʈʂɤ ʂʐ̩ | tsʰuŋ sən lin tɤ tsʰau ti li lai lɤ ji kɤ lau kuŋ kuŋ | ji kɤ mɑ mɑ xɤ tʰɑ tɤ ny ə̆ | hai jəu ji kɤ ɕjau waŋ tsz | ʈʂʰɥan ʂən təu ʈʂʰwan ʈʂɤ pʰwo tɕjəu tɤ ji fu | ɥy ʂʐ̩| pai ɥin ʂwo | ʈʂʐ̩ jau ʂwəi nəŋ raŋ ʈʂɤ sz kɤ rən pɑ ji fu tʰwo ɕj ɑ | tɕjəu swan ʂwəi tɤ pən ʂʐ̩ tɑ | rɑn xəu | tuŋ fəŋ tɕjəu ʈʂaŋ kʰai kʰəu | ʂʐ̩ tɕinə̆ tɤ ʈʂʰwəi | tan ʂʐ̩ | tʰɑ kwa tɤ ɥe juŋ li | tʰɑ mən sz kɤ tɕjəu pɑ ji fu lɑ tɤ kəŋ tɕin | tswəi xəu | tuŋ fəŋ ləi lɤ| je məi ʂən mɤ pan fɑ lɤ | ji xwəiə̆ | lwən tau tʰai jaŋ lɤ | tʰɑ mən ji kʰan tɕjan jaŋ kwaŋ | rɤ tɤ kʰwai kʰwai pɑ ji fu tʰwo lɤ ɕjɑ lai | swo ji | tuŋ fəŋ pu tɤ pu tʰuŋ ji | xai ʂʐ̩ tʰai jaŋ pi tɕjau tɕʰjaŋ |

Translation

The East Wind and the Sun

One noon, the White Cloud heard the East Wind and the Sun arguing, both claiming they were the stronger. Then from the forest grass came an old man, a mother and her daughter, as well as a little prince, all wearing ragged clothes. So the White Cloud said, the one who makes the four people take off their clothes should be considered stronger than the other. Then the East Wind opened his mouth and blew as hard as he could. However, the more he blew the more closely did the four of them fold their clothes around them. At last, the East Wind was exhausted and could not do anything more. Then the Sun shone out warmly, and as soon as they saw the Sun, they became hot and quickly took off their clothes. Therefore, the East Wind had no choice but to admit that the Sun was the stronger.

Appendix 2: The Discrimination Task

请你把 _____ 再说一遍。

1. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
2. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
3. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
4. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
5. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
6. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
7. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
8. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
9. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
10. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
11. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四
12. 你、发、力、鱼、妈、绿、是、女、子、姨、纸、四