

AN ARTICULATORY AND ACOUSTICAL ANALYSIS OF THE SYLLABLE-INITIAL SIBILANTS AND APPROXIMANT IN BEIJING MANDARIN

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ABSTRACT

This paper is an articulatory and acoustical analysis of the syllable-initial sibilants and approximant in Beijing Mandarin. Palatograms and linguagrams were obtained from young adult native speakers of Beijing, male and female, using the direct method. Results show that the initial consonants which are transcribed in earlier studies [3, 4, 10] as retroflexes [ʂ, ʈʂ, ʐ(ɹ)] are in fact apical or upperapical postalveolar fricative [ʃ], affricate [tʃ], and approximant [ɹ], respectively. Those as palatal sibilants [ç] and [tç] are in fact laminal or anterodorsal alveolar-postalveolar or postalveolar fricative [ʃ] and affricate [tʃ]. The frequency of the spectral energy is the highest for [s, ts], followed by [ʃ, tʃ] and [ɹ, tʃ] in decreasing order. The spectrum lengths of the sibilants are longer for the female speakers than the male speakers. The pattern of the F-values for [ɹ] for the female speakers differs from the pattern for the male speakers.

1. INTRODUCTION

Three types of sibilants are distinguished in Beijing Mandarin in Chao [3, 4] among other studies: (i) the plain dental sibilants [s, ts], (ii) the apical retroflexes [ʂ, ʈʂ, ɹ], and (iii) the palatals [ç, tç]. [ɹ] however is treated as [ʐ] in [10].

A recent study of syllable-initial sibilants in Beijing Mandarin by Ladefoged and Wu [9] based on the tracings of X-rays photographs and palatograms of three speakers reports that [s] is articulated with the tip of the tongue touching either the teeth, behind the teeth, or on the alveolar ridge. For all three Beijing speakers, "there is a hollowing of the tongue such that the tongue is concave with respect to the roof of the mouth" [9, p. 270]. The so-called retroflex fricative [ʂ] does not have the articulatory characteristics associated with a retroflex, i.e., curling the tip of the tongue up and back so that the underside of the tongue touches or approaches the back part of the alveolar ridge or the hard palate, such as the retroflexed consonants in Hindi [1, 2, 7]. Instead, the "front of the tongue" for all three speakers in [9] form a constriction at the center of the alveolar ridge. However, no information is given in [9] about the contact on the tongue, indicating whether the "front of the tongue" refers to the apex or blade. The description of the third type of the fricative in Beijing Mandarin as palatal in earlier studies [3, 4, 10] is inaccurate, as shown in [9] the narrowest channel for the fricative is near the front part of the alveolar ridge for two speakers, and further back for another. It is somewhere between the places for the plain denti-alveolar fricative and so-called retroflex fricative. No linguagraphic data are given in [9], specifying whether the sound is apical, laminal, or anterodorsal. As for the three

types of affricates in Beijing Mandarin, they have similar articulatory patterns to those of the corresponding fricatives.

However, [9] does not present linguagrams which are needed for more elaborated descriptions of the linguagraphic properties of the three types of sibilants, and no articulatory zones on the palatograms are identified in [9]. Also, the tracings of the X-rays of the fricatives and affricates in [9] are not easy to interpret. Furthermore, as "The X-ray photographs were taken while the subject was trying to maintain the articulatory posture for the initial consonant in a syllable" [9, p. 269], the X-ray data in [9] are records of articulatory gestures which lack spontaneity.

The present study is a palatographic, linguagraphic, and acoustical investigation of the three types of syllable-initial fricatives and affricates as well as the approximant in Beijing Mandarin. Palatograms and linguagrams as well as acoustical data of spectral energy are obtained from young adult native speakers of Beijing, male and female.

2. METHOD

In this study, the six syllable-initial sibilants as well as the approximant in Beijing Mandarin are analyzed for their articulatory and acoustical properties. The suggested IPA transcriptions and descriptions in this study and those in the earlier studies [3, 4, 10] of the sibilants and approximant under investigation are shown in Table 1.

IPA	Description
[s]	plain apical or laminal denti-alveolar or alveolar fricative (plain apical dental fricative [s])
[ʃ]	apical or upperapical postalveolar fricative (retroflex fricative [ʂ])
[ɹ]	apical or upperapical postalveolar approximant (retroflex approximant [ɹ] or voiced fricative [ʐ])
[ç]	laminal or anterodorsal postalveolar fricative (palatal fricative [ç])
[ts]	plain apical or laminal denti-alveolar alveolar affricate (plain apical dental affricate [ts])
[tʃ]	apical postalveolar affricate (retroflex affricate [ʈʂ])
[tʃ]	laminal or anterodorsal alveolar-postalveolar affricate (palatal affricate [tç])

Table 1. The suggested IPA transcriptions and descriptions of the syllable-initial sibilants and approximant in Beijing Mandarin in this study (earlier studies [3, 4, 10] in parentheses).

Meaningful monosyllables used as test words in this study are listed in Table 2. The speech data were provided by four university undergraduates, two male and two female, all native speakers of Beijing Mandarin.

Syllable-initials	Test monosyllables
[s]	[sɿŋ] "private"
[ʃ]	[ʃiŋ] "poetry"
[ɹ]	[ɹiŋ] "day"
[ʃ]	[ʃiŋ] "west"
[ts]	[tsɿŋ] "capital"
[tʃ]	[tʃiŋ] "to know"
[tʃ]	[tʃiŋ] "chicken"

Table 2. Meaningful test monosyllables used in this study.

In this study, the direct palatographic and linguagraphic method [5, 6] was adopted. Palatograms and linguagrams were taken, using a Polaroid Dine Instant Closeup Camera and a Nikon F-801s 35 mm camera. A dental-palate impression was made for each of the speakers, using the alginate impression material [8], to obtain personal anatomical information necessary for dividing the upper articulator into articulatory zones. The zones include "dental", "denti-alveolar", "alveolar", "postalveolar", "prepalatal", "palatal", and "velar" in the anterior-posterior dimension. The articulatory terminology specifying the division of the tongue in this study is similar to what is described in Catford [1, 2] and Dart [5, 6]. Thus, "apical" refers to the rim and apex of the tongue; "upperapical" refers to the upper surface of the apex, but not the rim, of the tongue; "laminal" refers to the blade of the tongue; "apicolaminal" refers to both the apex and blade of the tongue, with or without the contact on the rim of the tongue; "anterodorsal" refers to the anterodorsum or the front portion of the tongue body; and "sublaminal" refers to the underside of the tongue. To obtain the frequency energy of the sibilants, spectral analysis was performed at the mid-point of the frication of the fricatives and affricates, using Kay CSL4300B FFT power spectrum method. LPC formant analysis was performed to obtain the formant frequency values for the approximant, using the pitch synchronous method.

3. RESULT 1: ARTICULATORY CONTACTS

Plate 1 shows a photograph of the articulatory zones of the upper articulator for Female Speaker 1 of Beijing Mandarin, divided according to the anatomical features on her own dental-palate impression.

Plates 2a-2d show the palatograms (upper row) and linguagrams (lower row) of the three syllable-initial fricatives [s], [ʃ], and [ɹ] and approximant [ɹ], for Female Speaker 1. As can be seen, palatographically, the fricative [s] (Plate 2a) is an alveolar sound, with the front end of its constriction channel located at the root base of the frontal incisors. Linguagraphically, [s] is laminal, as the blade of the tongue is involved in the articulation.

The palatograms and linguagrams of the fricative [ʃ] and approximant [ɹ] (Plates 2b and 2c) show that they are postalveolar and upperapical sounds. This indicates that the tip of the tongue does not curl up and back and the underside of the tongue does not touch the rear part of the alveolar ridge as how a true retroflex is articulated [1, 2, 7]. Rather, during the

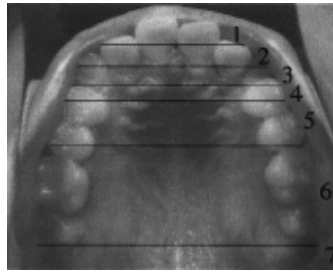
production of [ʃ] and [ɹ] the tip and body of the tongue are raised and retracted toward the postalveolar zone of the upper articulator. Thus, [ʃ] and [ɹ] in Beijing Mandarin are not retroflexes as what are described in [3, 4, 10]. The observation is similar to what is reported in [9]. As shown in the palatograms and linguagrams of [ʃ] and [ɹ], the front ends of the contacts on both sides of the tongue taper off toward the center line of the tongue to form the constriction channel on the upper surface of the apex. The tapering suggests that the front part of the tongue slightly folds inward during the contact. This and the raised tongue body may explain why the size of the lateral contact is relatively larger than the lateral contact for the laminal alveolar fricative [s].

The palatogram of the fricative [ʃ] in Plate 2d shows that the constriction channel is mainly in the postalveolar zone, even though the lateral contacts of [ʃ] in the palatal zone and on the tongue body are markedly larger than those associated with [s], [ʃ], and [ɹ]. Phonotactically [ʃ] (and [tʃ]) occurs only before the high front vowel [i] or [y] in Beijing Mandarin. Thus, the larger lateral contacts are due to palatalization of [ʃ] (and [tʃ] (Plate 3c)). Linguagraphically, [ʃ] is basically laminal, since the narrowest part of the constriction channel is on the blade. Thus, the fricative in question is laminal postalveolar, rather than palatal as transcribed in [3, 4, 10]. Again, the finding is similar to what is reported in [9].

Plates 3a-3c show the palatograms and linguagrams of the three syllable-initial affricates [ts], [tʃ], and [tʃ] in Beijing Mandarin by Female Speaker 1. A comparison of Plates 3a-3c with Plates 2a-2d shows that the palatograms and linguagrams of the fricatives [s], [ʃ], [ɹ] and approximant [ɹ] and those of the corresponding affricates [ts], [tʃ], [tʃ] are similar. However, the contacts for the affricates are fronted by approximately one articulatory zone on the upper articulator compared to those for the fricatives. Thus, while [s] is alveolar and [ʃ], [ɹ], [ɹ] are postalveolar, [ts] is denti-alveolar and [tʃ] alveolar. [tʃ], however, remains postalveolar despite being fronted slightly. In terms of lingual contact, [ts] remains laminal despite being fronted slightly, and [tʃ], [tʃ] are apical and upperapical, respectively.

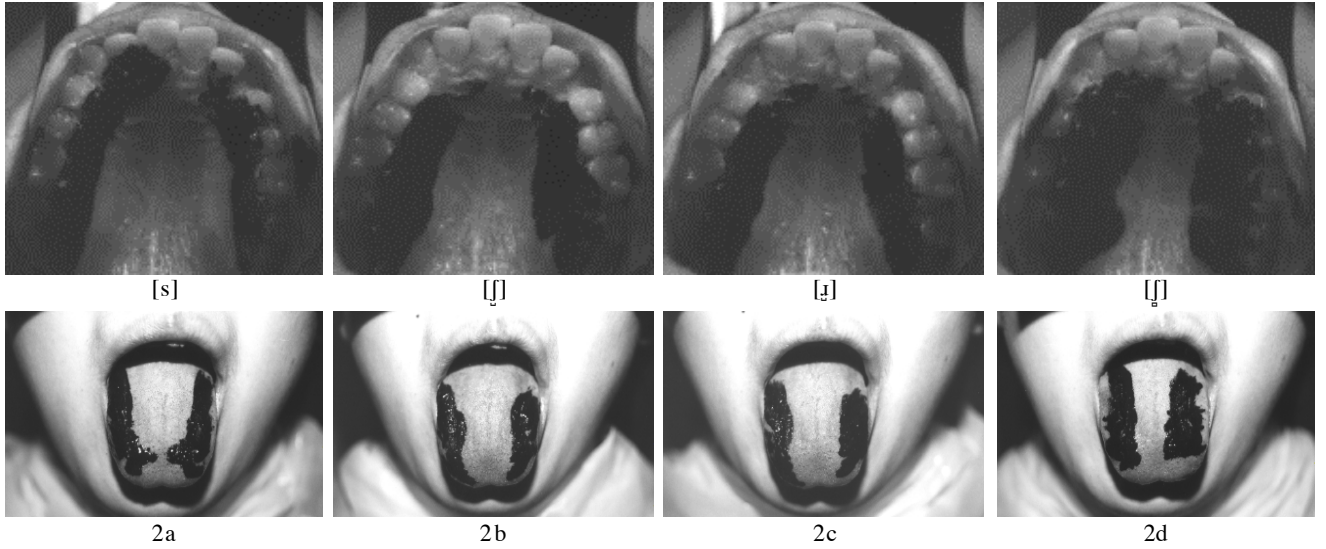
The linguagram of [tʃ] on the right in Plate 3b shows that the lingual contact of [tʃ] is on the rim as well as the apex, but not the underside, of the tongue. This constitutes evidence in support of the contention [tʃ], similar to [ʃ], is not a retroflex.

The articulatory data of the fricatives [s], [ʃ], [ɹ], affricates [ts], [tʃ], [tʃ], and approximant [ɹ] from Female Speaker 1 and the other three Beijing Mandarin speakers, Female Speaker 2 and Male Speakers 1 and 2, are summarized in Table 3. The patterns of articulatory contacts on the upper and lower articulators are similar for all four speakers. There are, however, some small variations among the speakers, for instance, palatographically [s] is alveolar for Female Speaker 1 and Male Speaker 1, but denti-alveolar for Female Speaker 2 and Male Speaker 2, and linguagraphically [s] is laminal for Female Speaker 1, upperapical for Female Speaker 2 and apical

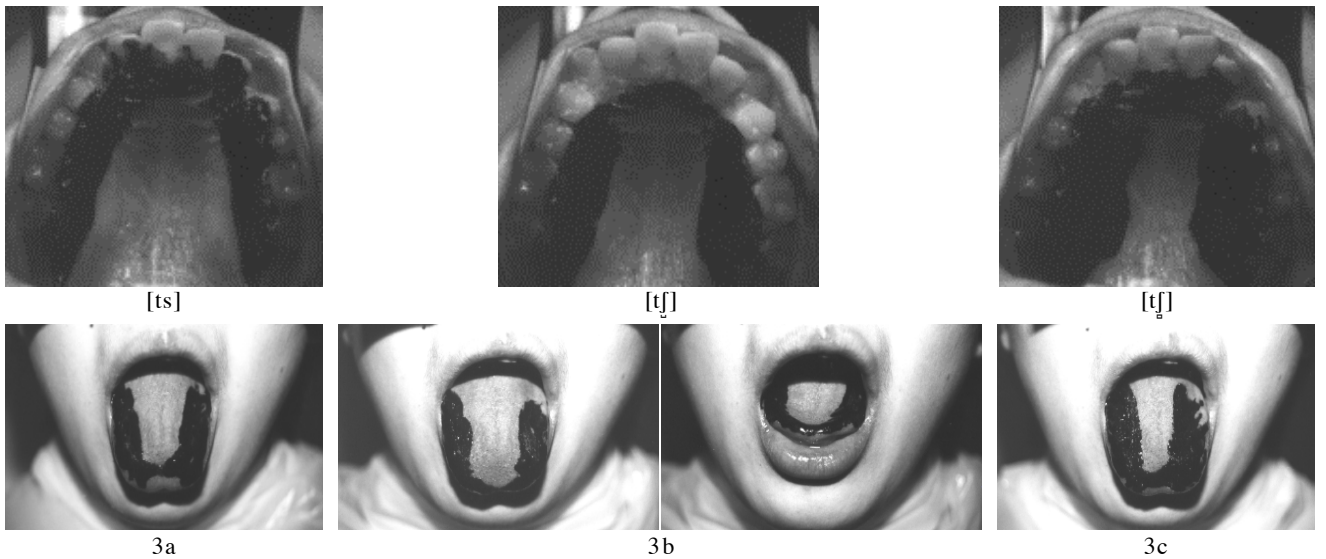


- 1 = "dental" zone
- 2 = "denti-alveolar" zone
- 3 = "alveolar" zone
- 4 = "postalveolar" zone
- 5 = "prepalatal" zone
- 6 = "palatal" zone
- 7 = "velar" zone

Plate 1. A photograph of the articulatory zones of the upper articulator for Female Speaker 1 of Beijing Mandarin in this study.



Plates 2a-2d. Palatograms (upper row) and linguagrams (lower row) of the syllable-initial [s], [ʃ], [ʒ], and [ʒ̥] in Beijing Mandarin for Female Speaker 1 in this study.



Plates 3a-3c. Palatograms (upper row) and linguagrams (lower row) of the syllable-initial [ts], [tʃ], and [tʃ̥] in Beijing Mandarin for Female Speaker 1 in this study.

for both Male Speakers 1 and 2. As shown in Table 3, there is more speaker variation in lingual contact than the contact on the upper articulator. This may seem to suggest that (i) reaching the exact contact targets on the upper articulator is more important than the lower articulator, (ii) reaching the exact contact targets on the upper articulator is easier than the lower articulator, or (iii) the articulatory zones on the upper articulator can be better defined than the lower articulator. Whatever the explanation may be, there is less speaker variation in reaching the contact targets on the upper articulator.

	Female Speaker 1	Female Speaker 2	Male Speaker 1	Male Speaker 2
[s]	"alveolar" "laminal"	"denti-alveolar" "upperapical"	"alveolar" "apical"	"denti-alveolar" "apical"
[ts]	"denti-alveolar" ↔"alveolar" "laminal"	"denti-alveolar" ↔"alveolar" "laminal"	"denti-alveolar" ↔"alveolar" "apicolaminal"	"denti-alveolar" ↔"alveolar" "apical"
[ʃ]	"postalveolar" "upperapical"	"postalveolar" "upperapical"	"postalveolar" "apical"	"postalveolar" "apical"
[ʒ]	"postalveolar" "upperapical"	"postalveolar" "upperapical"	"postalveolar" "apical"	"postalveolar" "apical"
[tʃ]	"postalveolar" "apical"	"postalveolar" "apical"	"postalveolar" "apical"	"postalveolar" "apical"
[ʒ]	"postalveolar" "laminal"	"postalveolar" "laminal"	"postalveolar" "anterodorsal"	"postalveolar" "anterodorsal"
[tʃ]	"alveolar" ↔ "postalveolar" ↔ "upperapical" ↔ "laminal"	"alveolar" ↔ "postalveolar" ↔ "laminal"	"alveolar" ↔ "postalveolar" ↔ "laminal"	"alveolar" ↔ "postalveolar" ↔ "anterodorsal"

Table 3. Palatographic and linguagraphic contact locations of the sibilants and approximant in Beijing Mandarin for two male and two female speakers in this study.

4. RESULT 2: ACOUSTICAL PROPERTIES

The results of the spectral analysis of the syllable-initial fricatives, affricates, and approximant in Beijing Mandarin for two male and two female speakers are summarized in Table 4.

	Female Speaker 1	Female Speaker 2	Male Speaker 1	Male Speaker 2
[s]	5-14 kHz	9-14 kHz	5-11 kHz	4-10 kHz
[ts]	5-13 kHz	8-14 kHz	5-9 kHz	4-9 kHz
[ʃ]	2-10 kHz	2-10 kHz	2-8 kHz	2-7 kHz
[tʃ]	2-10 kHz	2-10 kHz	2-7 kHz	2-7 kHz
[ʒ]	3-11 kHz	5-12 kHz	3-10 kHz	3-9 kHz
[ʒ]	3-11 kHz	4-11 kHz	3-9 kHz	3-8 kHz
[ɹ]	332 Hz 1,919 Hz 2,234 Hz	267 Hz 1,880 Hz 2,151 Hz	272 Hz 1,665 Hz 2,713 Hz	309 Hz 1,629 Hz 2,712 Hz

Table 4. Frequency ranges of the spectral energy of the sibilants and approximant in Beijing Mandarin for two male and two female speakers in this study.

The table shows the frequency range of the spectral energy for each of the sibilants [s, ʃ, ʒ, ts, tʃ, tʃ]. The frequency of the spectral energy is the highest for [s, ts], followed by [ʃ, tʃ] and [ʒ, tʃ] in decreasing order. This is true for all four speakers.

However, the spectrum lengths of the sibilants are longer for the female speakers than the male speakers, although the initial frequency at which energy is visible is not necessarily higher for the female speakers than the male speakers. Table 4 also shows the F-values for the approximant [ɹ]. The patterns of the F-values for the approximant between the male and female speakers differ. The absence of frication disproves the treatment of the sound as a voiced fricative in [10].

5. CONCLUSION

The paper has presented palatographic and linguagraphic data of the syllable-initial fricatives [s, ʃ, ʒ], affricates [ts, tʃ, tʃ], and approximant [ɹ] in Beijing Mandarin from two male and two female young adult speakers. The data which support the findings in [9] serve as evidence against the assumptions made in earlier studies [3, 4, 10] that in Beijing Mandarin there are (i) retroflex fricatives, affricates, and approximant [3, 4, 10], (ii) palatal fricatives and affricates [3, 4, 10], and (iii) voiced retroflex fricative [10]. This study has shown that the so-called retroflexes are in fact apical or upperapical postalveolar fricative, affricate, and approximant, and the so-called palatals are in fact laminal or anterodorsal alveolar-postalveolar or postalveolar fricative and affricate. Furthermore, the lack of frication indicates that the approximant cannot be a voiced retroflex fricative as described in [10]. The data also provide a basis for the IPA transcriptions of the syllable-initial consonants suggested in this study.

The articulatory and acoustical data presented in this study show that while there is only minor variation in the locations of articulatory contacts between male and female speakers, there is significant difference in frequency value for the sibilants and approximant between male and female speakers. This suggests that the difference in acoustical quality of the sibilants and approximant between male and female speakers is not attributed to articulatory difference, but other factors.

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REFERENCES

- [1] Catford, J. C. 1977. *Fundamental Problems in Phonetics*. Bloomington: Indiana University Press.
- [2] Catford, J. C. 1988. *A Practical Introduction to Phonetics*. Oxford: Clarendon Press.
- [3] Chao, Y. R. 1948. *Mandarin Primer*. Cambridge, Massachusetts: Harvard University Press.
- [4] Chao, Y. R. 1968. *A Grammar of Spoken Chinese*. Berkeley and Los Angeles: University of California Press.
- [5] Dart, S. N. 1991. Articulatory and Acoustic Properties of Apical and Laminal Articulations. *UCLA Working Papers in Phonetics*, 79. University of California, Los Angeles.
- [6] Dart, S. N. 1998. Comparing French and English coronal consonant articulation. *Journal of Phonetics*, 26, 71-94.
- [7] Ladefoged, P. 1993a. *A Course in Phonetics* (3rd edition). New York: Harcourt Brace Jovanovich.
- [8] Ladefoged, P. 1993b. Linguistic phonetic fieldwork: a practical guide. *UCLA Working Paper in Phonetics*, 84, 1-24. University of California, Los Angeles.
- [9] Ladefoged and Wu, Z. J. 1984. Places of articulation: an investigation of Pekingese fricatives and affricates. *Journal of Phonetics*, 12, 267-278.
- [10] Yuan, et al. 1960. *Hanyu Fangyan Gaiyao* (A Precise of the Chinese Dialects). Beijing: Wenzhi Gaige Chubanshe.