Perception of Gesturally Different Mandarin Retroflexes by Taiwan

Mandarin Speakers

Zhe-Chen (Adam) Guo

National Sun Yat-Sen University

Table of Contents

Abstract.....	3
1 Introduction.....	3
2 Literature Review.....	5
2.1 Articulation.....	6
2.1.1 Common Beliefs About Mandarin zh, ch, sh, and r.....	6
2.1.2 The Retroflex Gesture Employed by Native Speakers of Beijing Mandarin: An Investigation by Ladefoged & Wu (1984).....	7
2.1.3 Questions as to the description as “retroflex”.....	9
2.2 Acoustic properties.....	9
2.2.1 Formant frequencies.....	9
2.2.2 Spectral energy distribution.....	10
2.3 A conclusion of the literature review.....	11
3 Methodology.....	12
3.1 Perception test.....	12
3.1.1 Sound stimuli.....	12
3.1.2 Participants.....	13
3.1.3 Procedures.....	13
3.2 Acoustic analysis.....	14
4 Results.....	14
4.1 Participant data.....	14
4.2 The results of Task 1.....	14
4.3 The results of Task 2.....	15
4.4 The results of the acoustic analysis.....	16
5 Discussion.....	17
5.1 TM listeners’ perception at a phonological level.....	17
5.2 TM listeners’ perception at a phonetic level.....	17

5.3	TM listeners' perception of the acoustic property	18
5.4	Research limitations.....	18
6	Conclusion	19
	References.....	21
	Appendix A.....	23
	Appendix B.....	25

Abstract

This paper reports results from a study investigating whether there is a perceptual difference between gesturally different Mandarin retroflexes. Previous studies have suggested that there are two articulatory manners for Mandarin retroflexes: One involves the tongue tip being “curled-up,” and the other the tongue body being “bunched-up.” Thus, by implementing a perception test on Taiwan Mandarin listeners and an acoustic analysis, the research determines whether retroflexes produced with these gestures will be perceived differently. The results then show that “curled-up” and “bunched-up” retroflexes are not perceptually contrastive at a phonological level. However, the latter are perceived to be phonetically more retroflexed, with such property of stronger retroflexion reflected in their lower M1 (first moment) values. These findings yield one pedagogical implication. The teaching of retroflex articulations can be made reference to the gesture with which Mandarin learners can produce with more ease.

1 Introduction

This paper explores effects of the differences between articulatory gestures for Mandarin retroflexes on Taiwan Mandarin (TM) speakers’ perception and analyzes these effects in relation to acoustic properties. Mandarin consonantal inventory has four segments considered to be retroflex—*zh*, *ch*, *sh*, and *r*¹. These sounds are generally associated with tongue-tip curling or raising, the typical feature of retroflexes, and most pedagogical materials and books on Chinese sounds (e.g. Pan & Chen, 1987; Yeh, 1994; Lee, Dai, & Guo, 1995; Lu, 2006) also describe them in

¹ The pinyin spellings and zhuyin symbols of Mandarin retroflexes, which include two fricatives and two affricates, are given in Table 1.

similar ways. But a preliminary literature review revealed that the actual retroflex gesture employed by native Beijing Mandarin speakers is one involving a lowered tongue tip and a bunched-up tongue body (Ladefoged & Wu, 1984). These intriguing findings about articulation laid a foundation for the current study.

Table 1 The IPAs, pinyin spellings, and zhuyin symbols for Mandarin retroflexes

IPA	Pinyin	Zhuyin
[tʂ]	‘zh’	‘ㄓ’
[tʂʰ]	‘ch’	‘ㄔ’
[ʂ]	‘sh’	‘ㄕ’
[ʐ] or [ɻ] ²	‘r’	‘ㄖ’

But those findings alone do not suffice to provide reasons for doing research on perception and acoustics. In effect, the present research was motivated by a possible explanation for the discrepancy described above that was derived from a further literature review about the acoustic aspect of retroflex sounds. The review offers an acoustic view of what constitutes “retroflexion.” For instance, all retroflexes cause the lowering of certain formants (Jakobson, Fant, & Halle, 1951; Ladefoged, 2001: 212–214, as cited in Wan & Jaeger, 2003; Joos, 1948). It was therefore concluded that retroflex, which traditionally describes “a place of articulation” (Ladefoged & Johnson, 2006), can be rethought in terms of acoustic characterization.

This conclusion would be satisfactory in the sense that it may explains why Beijing Mandarin speakers’ *zh*, *ch*, *sh*, and *r* are still regarded as “retroflexes.”

² The underlying phoneme of [ʐ] is /ɻ /; it will be pronounced as either [ɻ] (a voiced retroflex approximant) or [ʐ] (a voiced retroflex fricative), depending on the speaker.

However, there are a few questions left unanswered: Do *zh*, *ch*, *sh*, and *r* articulated with a curled-up tongue tip and those pronounced with a bunched-up tongue body sound the same in the ears of Mandarin speakers? Do the two types of gestures differ in acoustics? And if the answer to these two questions is “yes,” then does the perception of retroflexes produced with the two gestures correlate with their acoustic differences?

These questions are crucial when answers to or explanations for them can provide suggestions for pedagogical practices as well as research on this topic. For example, if one gesture proves to be significantly more retroflexed than the other in terms of perception, Mandarin learners and instructors would have reasons to choose the former since it can minimize miscommunication. In contrast, if the two types of retroflexes are perceived equally well to be retroflex, learners and instructors can opt for the one which is articulatorily easier. Based on the results of the research, this paper is hoped to shed some light on those questions and propose suggestions.

The paper includes six sections: 1) Introduction; 2) Literature Review; 3) Methodology; 4) Results; 5) Discussion; and 6) Conclusion.

2 Literature Review

This section begins with a description of articulatory gestures suggested for Mandarin retroflexes in studies and teaching/learning materials. It leads to an assumption that the gestures can generally be divided into two types. Then, an explanation from an acoustic perspective is proposed to account for the two kinds of gestures. Finally, questions whether there will be gestural differences between the two types in acoustic and auditory aspects are asked.

2.1 Articulation

2.1.1 *Common Beliefs About Mandarin zh, ch, sh, and r*

The Chinese name for retroflexes (捲舌 ‘curling the tongue’) exemplifies a belief in Mandarin speakers’ knowledge with respect to retroflexes: They are sounds articulated by curling the tongue tip upwards or backwards. In this case, Mandarin *zh*, *ch*, *sh*, and *r*, which are generally considered retroflex, are naturally associated with such articulatory gesture. This association is evidenced by a number of books and pedagogical materials (Pan & Chen, 1987; Yeh, 1994; Li, Dai, & Guo, 1995; Lu, 2006; The Editorial Board of Chinese Phonetics of National Taiwan Normal University, 2007), which described the retroflex sounds in similar ways. For instance, in the illustration in Figure 1, which is cited from Yeh (1994), it can be seen that *zh*, *ch*, *sh*, and *r* are all characterized by a tongue tip being curled upwards.

As the aforementioned references conform to the belief commonly held by Mandarin speakers, there seems to be no consensus on the side of tongue tip involved in the articulation of *zh*, *ch*, *sh*, and *r* as well as the extent to which one should curl or raise their tongue tip. According to Ladefoged & Maddieson (1996), the retroflex sounds in, for example, Yeh’s (1994) illustrations, can be described as sub-apical because they are produced with the underblade of the tongue. Yet, Lee and Zee (2003, as cited in Lin, 2007) and Zee (2003a, as cited in Lin, 2007) uphold the view that the sounds in question are actually made with the upper side of the tongue tip. Besides, different references present different articulation diagrams with different degrees of tongue tip raising or curling. For instance, for the sound *sh*, the tongue tip is curled much more upwards and backwards in a book by the editorial committee of National Taiwan Normal University (2007) than in Wan (2005) (see Figure2).

Despite inconsistency among these references, they seem to agree on one thing: *zh*, *ch*, *sh*, and *r* involve tongue tip curling or raising as a necessary feature. However, Mandarin retroflexes with such feature will form a particular type (which, for convenience, will be referred to ‘curled-up’ type) when they are compared with another kind of Mandarin retroflexes, which will be described in the next subsection.

Figure 1 From left to right, the tongue gestures of *zh*, *ch*, *sh*, and *r* (Yeh, 1994)

Figure 2 A comparison between *sh* in Wan (2005: 73, the figure on the left) and that in a book by the editorial committee of National Taiwan Normal University (2007: 140)

2.1.2 *The Retroflex Gesture Employed by Native Speakers of Beijing Mandarin: An Investigation by Ladefoged & Wu (1984)*

In a study by Ladefoged & Wu (1984), it can be observed that native speakers of Beijing Mandarin actually produce the so-called retroflexes in Mandarin without raising or curling the tongue tip. In their experiments, three participants—all native speakers of Beijing Mandarin—were asked to enunciate Mandarin fricative and affricate sounds, which included the retroflex ones. When the speakers retained the

gestures for the sounds, X-ray photographs were taken. One of the findings is that these speakers lowered their tongue tips and bunched their tongue bodies up, as shown in Figure 3.

Figure 3 The X-ray photographs of the speakers saying *zh*, *ch*, and *sh* (Ladefoged & Wu, 1984: 269-273)

Since there is no tongue-tip curling or raising in *zh*, *ch*, and *sh* of the speakers of Ladefoged & Wu (1984), the sounds are by no means (sub-) apical post-alveolars. While a more appropriate description is necessary, Ladefoged and Maddieson (1996) has in fact suggested a term for the sounds in question. Based on the results of Ladefoged & Wu, a small section in Ladefoged & Maddieson particularly deals with the sound *sh*. Ladefoged & Maddieson contends that the sound should be a “laminal flat palato-alveolar sibilant” and therefore that “the traditional description of this sound [‘*sh*’] as a retroflex is inappropriate as a description of its articulation” (p.153). Distinguished from the “curled-up” retroflexes illustrated above, these *zh*, *ch*, and *sh*

produced with a lowered tongue tip and a bunched-up tongue body can be grouped into a type, which is labeled as “bunched-up” here.

2.1.3 Questions as to the description as “retroflex”

If Mandarin *zh*, *ch*, *sh*, and *r* are actually bunch-up (or laminal flat palato-alveolar sibilants, as suggested by Ladefoged & Maddieson, 1994), then there are still questions regarding these sounds and the term “retroflex.” Can they really be described as retroflex? If they are, what are the common properties shared by this type of Mandarin retroflexes and its “curl-up” counterpart? If they are not, why is there a general association of bunched-up *zh*, *ch*, *sh*, and *r* with “retroflex”?

An explanation for this came from a further literature review on the acoustics of sounds. The rationale for examining the acoustic dimension was to know whether those “bunched-up” retroflexes have non-articulatory properties characterizing all retroflex sounds.

2.2 Acoustic properties

One way to address the questions surrounding what is “retroflex” is to examine retroflexion acoustically. The subsection here will deal with two retroflex features in acoustics: One is the formant frequencies of vowels following retroflexes; the other is the spectral distribution of energy in the frication of retroflex consonants.

2.2.1 Formant frequencies

One of the typical effects of retroflexion on the formant frequencies of sounds is the lowering of the first three formants, particularly the third (Jakobson, Fant, & Halle, 1951; Ladefoged, 2001: 212–214, as cited in Wan & Jaeger, 2003). Thus, a comparison between “bunched-up” retroflexes (such as those produced by Beijing Mandarin speakers) and their alveolar counterparts can determine whether the former

have the same retroflex effect on formants. Yet, unfortunately, no previous research on Mandarin retroflex that specifically points out the gestures with which the retroflexes are produced could be found. For this reason, a small-scale experiment was carried out on one TM speaker. The speaker pronounced alveolar *za*, *ca*, and *sa* and then used “bunched-up” gesture to articulate *zha*, *cha*, and *sha*. As shown in Figure 4, which compares the spectrogram of the speaker’s *sha* with that of his *sa*, the results conform to what has been suggested for the effects of retroflexion on formant frequencies: the lowering of the third formant.

Figure 4 The spectrograms of *sha* and *sa* produced by the speaker

2.2.2 Spectral energy distribution

In addition, the retroflex and alveolar sounds in question differ in the pattern of spectral energy distribution, which can be investigated by means of the moments analysis. Having been employed by acoustic studies such as Jeng (2006, 2009) and Chang (2001), the moments analysis is used to quantify the energy distribution of

aperiodic sounds (e.g. voiceless fricatives and stops). In Jeng (2006), the method uses four parameters (M1, M2, M3 and M4³) to characterize the energy distribution of fricative noise of Mandarin retroflex-alveolar contrasts. For instance, M1 represents the mean frequency of energy distribution; thus, higher M1 means that most of the energy is distributed over higher frequencies whereas lower M1 means that most is concentrated at lower frequencies. The results of Jeng show that the retroflex *zh*, *ch*, and *sh* have lower M1 and M4 but higher M2 and M3, compared with the alveolar *z*, *c*, and *s*. Consequently, the Mandarin retroflex and alveolar contrasts are acoustically characterized by differences in distributive patterns of spectral energy.

In fact, these results supports the claim that the “bunched-up” share similar features with typical retroflexes, for they are consistent with those of the aforementioned experiment on the TM speaker. As shown in Figure 4, more energy (which is indicated by darker patches) is concentrated at around the frequencies F3 for *sh* in *sha*. In contrast, the energy of *s* in *sa* is mainly distributed over the higher frequencies which are partially not presented in the figure⁴. Despite being produced with the “bunched-up” gesture, the retroflexes cause spectral effect typical of retroflex sounds.

2.3 A conclusion of the literature review

As far as the acoustic aspect is concerned, there is one possible explanation which may resolve the problem of conflicting suggestions as to the articulations of the Mandarin retroflex: The “bunched-up” retroflexes have typical acoustic features of

³ M1 represents the mean frequency of spectral energy distributed over the full range of frequencies, M2 stands for the degree of energy dispersion, M3 signifies the skewness of energy, and M4 is the value of the kurtosis of energy distribution (Jeng, 2006).

⁴ Although the distribution of the energy can be clearly seen in the consonants, more careful methods like the moment analysis should be used to reduce arbitrary judgments.

retroflexion. However, the perceptual aspect of the gestural difference and its auditory effects on Mandarin listeners are still unexplored. As a result, of the greatest interest here are two questions concerning the “curled-up” and “bunched-up” retroflexes: Will such gestural difference also differ acoustically? More importantly, will “curled-up” and “bunched-up” retroflexes be perceived differently by Mandarin listeners? These will be addressed in the present study, and the following section will first describe the approach to the questions.

3 Methodology

The current study investigates whether the gestural discrepancy between “bunched-up” and “curled-up” retroflexes causes perceptual differences for Taiwan Mandarin speakers and whether these differences are correlated with the acoustic properties of the retroflexes. Thus, the methods involves 1) a perception test on a group of TM speakers as well as 2) an acoustic analysis of the sound tokens used in the test.

3.1 Perception test

3.1.1 *Sound stimuli*

Before the experiment on those speakers, the sound tokens of the test were designed and prepared. Selected as sound stimuli are 12 Mandarin monosyllabic words, in which six ones belong to “retroflex” group and the other six ones to “non-retroflex (alveolar)” group. For the words in the “retroflex” group, three retroflex initial consonants (‘zh,’ ‘ch,’ and ‘sh’) respectively combine with a following vowel ‘u’ or ‘a.’ Similarly, every word in the “non-retroflex” group comprise an initial consonant preceding ‘u’ or ‘a,’ but the consonants in this group were all alveolar (‘z,’ ‘c,’ and ‘s’). Thus, there are six permutations in both groups.

3.1.2 Participants

The participants included one male TM speaker as the sound informant and 37 college students from a university in Southern Taiwan as the subjects in the perception test. Before the test, the male TM speaker was chosen as the informant since he was capable of producing both curled-up and bunched-up Mandarin retroflexes. He was asked to provide sound tokens for the aforementioned 12 Mandarin words: First, for the “retroflex” group, he pronounced the six words with bunched-up gesture and then with curled-up gesture; then, for the “non-retroflex” group, the informant produced all the words once and with the same alveolar gesture. Thus, there were 12 sound tokens in the “retroflex” group, which can be further divided into “bunched-up” (hereafter “BU”) subgroup and “curled-up” (hereafter “CU”) subgroup, and in total there were 18 tokens. Finally, all the tokens were recorded in mono through the computer program Goldwave in a recording studio.

These tokens were used as the stimuli of the test for the 37 college students, eight of whom were male and 29 of whom were female.

3.1.3 Procedures

The perception experiment on the 36 participants consisted of two tasks. First, they listened to the 18 tokens, which were arranged in a random order, and then judged if the one they just heard belonged to the “retroflex” group or not. In the second part, the same set of tokens was played back to the subjects but in a different order. This time they were instructed to rate the degree of “retroflexion” for each token on a scale of 1-5, where 1=non-retroflex and 5=strongly retroflexed (Refer to Appendix A for the Chinese version of the answering sheet and the Appendix B for the English version).

3.2 Acoustic analysis

Applied to examine the acoustic properties of the tokens was the moments analysis⁵. As in Jeng (2006), the time-frequency analysis software program TF32 (Milenkovic, 2004, as cited in Jeng, 2006) was employed to process the tokens on the computer. What was measured using this program was the M1 values of the consonant segment in each token, since Jeng (2009) suggested that M1 is the parameter which can best distinguish retroflex segments from alveolar ones. Then, the M1 values were compared with the test results to determine if there were any correlations.

4 Results

4.1 Participant data

There were 37 respondent data collected from those TM participants, with one deleted from all analyses because the subject missed one question in the second part of the experiment. As a result, there were 36 valid data left.

4.2 The results of Task 1

Shown in Table 3 are the identification rates for the BU retroflex group, the CU retroflex group, and alveolar group. Correct response received one point, while no scores were given to the incorrect ones. Then, each correct identification rate was calculated by dividing the number of correct responses by that of all the 36 subjects' responses to six stimuli (36 subjects x 6 types of stimuli).

⁵ The literature review has indicated that both the lowering of vowel formants and the M1 of consonants are parameters of retroflexion. Unfortunately, due to the lack of instruments for measuring vowel formants accurately, only M1 was included as a tool for analyzing the tokens

Besides, an independent *t*-test was conducted on the participants to know whether gender correlated with their identification rates. The results showed that no differences were found between the task performance of males and females participants ($p > .10$).

Table 2 The correct identification rates for the BU retroflex group, the CU retroflex group, and alveolar group ($N=216$ for each group)

BU retroflexes	CU retroflexes	Alveolar (non-retroflexes)
99.54%	98.61%	88.89%

4.3 The results of Task 2

The second task investigated the presence/absence of gestural effects (i.e. bunched-up vs. curled-up gestures) on the participants' rating of the retroflex tokens. Yet, in addition to the gesture, there were two other variables that might play a role in the participants' rating: the consonant type ('*zh*,' '*ch*,' and '*sh*') and the vowel ('*a*' and '*u*'). Consequently, a more rigorous way to deal with the data at hand was to consider all the three variables and conduct a repeated measure ANOVA. The results of the ANOVA test are shown in Table 4-6, each of which deals with a particular variable and presents the total scores, the mean scores, and the standard deviations (SD) for groups involved⁶ as well as the significance of the difference between the groups:

Table 4 The variable of "gesture" ($N=36$)

Groups	Total score	Mean	SD
Curled-up retroflexes	969	26.9**	3.0

⁶ Every score datum in a group was derived from adding up the individual participant's scores given to tokens classified into this particular group. And the grouping of the tokens depended on the variable under investigation.

Bunched-up retroflexes	1016	28.2	2.3
------------------------	------	------	-----

** $: p < .01$

Table 5 The variable of “consonant type” (N=36)

Groups	Total score	Mean	SD
Initial consonant ‘zh’	661	18.4*	2.2
Initial consonant ‘ch’	653	18.1	1.9
Initial consonant ‘sh’	671	18.6	1.9

* $: p < .05$

Difference at the significance level of .01 was indicated by two asterisk marks (**), and a single asterisk (*) represented difference at the significance level of .05.

Table 6 The variable of “vowel” (N=36)⁷

Groups	Total score	Mean	SD
Vowel ‘u’	1167	32.4	2.7
Vowel ‘a’	1162	32.3	3.3

Another independent *t*-test performed on these 36 TM subjects suggested that the subjects displayed no gender differences in the ratings of the BU retroflex group, the CU retroflex group, and also the alveolar group ($p > .10$ for all the three groups).

4.4 The results of the acoustic analysis

After the M1 value of frication was measured for each of the 18 tokens, the mean M1 and SD for each of the three groups (the BU retroflex group, the CU retroflex group, and the alveolar group) were then calculated. The results are presented in Table 7.

⁷ The statistical analysis of this variable involved the vowels in both “retroflex” and “non-retroflex” groups.

Table 7 The mean M1 value and SD (kHz) for the BU retroflex group, the CU retroflex group, and the alveolar group

	BU retroflexes	CU retroflexes	Alveolar (non-retroflexes)
Mean M1	3.181	3.56	4.596
SD	0.248	0.242	0.335

5 Discussion

The section will discuss the data obtained from the experiment and the acoustic analysis. Derived from this discussion is an interpretation which can account for the participants' perception at a phonological level, their perception at a phonetic level, and their perception of the retroflex acoustic property. Also, in this section the researcher will acknowledge the limitations of the current study.

5.1 TM listeners' perception at a phonological level

The TM participants' high identification rates in the task 1 leads to the explanation that the gestural difference between BU and CU retroflexes did not cause perceptual differences at a phonological level. Since in the first task the listeners were instructed to judge if a token belonged to the "retroflex" group or not, this task required categorization of perceived stimuli into phonological representations of either retroflex or alveolar sounds. Their identification of the retroflex tokens at a near perfect rate (98.61% for CU retroflexes and 99.54% for BU ones) suggests that the retroflexes—albeit produced with different gestures—do not contrast phonologically.

5.2 TM listeners' perception at a phonetic level

However, when perception here refers to perception in a broader sense, this explanation alone does not suffice to conclude that the BU and CU retroflexes caused no auditory differences in the participants. In fact, the results obtained from the second task show that the BU retroflexes were perceived to be more retroflexed than

the CU ones. In the task, the TM listeners indicated the degree of retroflexion on a scale of 1-5; in other words, they were asked to respond to phonetically-relevant property of retroflexion. In this way, the difference between gestures at the significance level of .001 indicates that they were capable of detecting the difference between BU and CU retroflexes and that they generally considered the former to be more retroflexed (the mean of BU retroflexes=28.2; the mean of CU retroflexes=26.9).

5.3 TM listeners' perception of the acoustic property

In support of the interpretation above are the results from the acoustic analysis. As shown in Table 7, the average M1 for the BU group and that for CU group differ by approximately 380 Hz. Therefore, it can be assumed that the participants might be sensitive to this acoustic disparity and respond to it by giving higher scores to the BU group.

In sum, based on the discussion of the data, one interpretation is proposed here: The difference between the BU and CU types is perceptible by the TM listeners, although they are not so different as to affect the TM participants' perception at a phonological level.

5.4 Research limitations

Although the assumption can account for the patterns of the participants' responses to the BU and CU retroflexes, there are a few methodological difficulties which limit the interpretability of the assumption. These include the problems with the representativeness of the TM participants, the consonant types of the tokens, as well as the "cured-up" retroflexes of the sound informant. First, all of the TM listeners were college students from a university in Southern Taiwan; thus, their perception of BU and CU gestures may represent, for example, only a particular age group. Then,

since the ANOVA test reveals that the types of initial consonant had a minor effect on the TM listeners' rating, there is the likelihood that they would display rating patterns different from the current one if the consonants were, for instance, all 'ch.' Finally, the literature review has previously point out different degrees of tongue-tip curling for CU retroflexes; thus, the informant might produced only a particular type of CU retroflexes. Perhaps multiple Mandarin speakers using the CU gesture should be recruited to elicit more ecologically-valid stimuli.

6 Conclusion

The current research yielded a few notable findings. First, the TM participants did not perceived retroflexes of these two types to be phonologically distinct. However, when instructed to respond to the phonetic feature of retroflexion, the participants generally rated the BU tokens as more retroflexed than the CU tokens. This could probably be attributed to the fact that the BU gesture also results in more retroflexion in acoustics than the CU one does.

This paper provides pedagogical implications for teaching Chinese as a foreign language. As far as communication with native TM speakers is concerned, neither CU nor BU will retroflexes cause misinterpretation since retroflexes of these two types were perceived equally well as retroflexes. This implies that Mandarin teachers can focus on the articulatory aspect of Mandarin retroflexes and base their teaching of retroflex articulations on the gesture with which their students are able to produce with more ease. For example, if native speakers of a particular foreign language generally feel that the CU retroflexes taught in most of Mandarin pedagogical materials are difficult while there are sounds similar to the BU retroflexes in their native language, Mandarin teachers can adjust their traditional pedagogy. In this way,

they can facilitate their students' acquisition of Mandarin retroflexes and at the same time promote their intelligibility in their communication with native TM speakers.

References

- Jakobson, R., G. Fant, & M. Halle (1951). *Preliminaries to Speech Analysis: The Distinctive Features and their Correlates*. Cambridge, Mass.: MIT Press.
- Jeng, J.-Y. (2006). The acoustic spectral characteristics of retroflexed fricatives and affricates in Taiwan Mandarin. *Journal of National University of Tainan: Humanities Study*, 40(1), 27-48.
- Jeng, J.-Y. (2009). The auditory discrimination of Mandarin retroflex contrasts and spectral moment analysis. *Chinese Journal of Psychology*, 51(2), 157-173.
- Ladefoged, P. (2001). *A Course in Phonetics* (5th edition). Harcourt College Publishers, Fort Worth.
- Ladefoged, P., & Maddieson, I. (1996). *The Sounds of the World's Languages*. Oxford: Blackwell Publishers.
- Ladefoged, P., & Wu, Z.-J. (1984). Places of articulation: An investigation of Pekingese fricatives and affricates. *Journal of Phonetics*, 12(3), 267-78.
- Lee, X.-Q., Dai, G.-F., & Guo, Z.-H. (1995). *A New Perspective: Context, Function, and Structure in Teaching Chinese*. Beijing: Peking University Press.
- Lee, W.-S., & Zee, E. (2003) Standard Chinese (Beijing). *Journal of the International Phonetic Association*, 33: 109-12.
- Lin, Y.-H. (2007). *The Sounds of Chinese*. New York: Cambridge University Press.
- Lu, Q.-H. (2006). *Shíyòng duì wài Hànyǔ jiāoxué yǔfǎ* [A practical grammar book for teaching Chinese as a foreign language.]. Beijing: Peking University Press.
- Milenkovic, P. (2004). *TF32* [Computer program]. Madison, WI: University of Wisconsin-Madison, Department of Electrical Engineering.
- Pan, Z.-G., & Chen, S.-T. (1978). *Zhōng guó shēngyùnxué* [Chinese Phonology]. Taipei: The Grand East Book Co.

The Editorial Board of Chinese Phonetics Pedagogical Materials of National Taiwan Normal University. (2009). *Guó yīn xué* [Chinese Phonetics]. Taipei: Cheng Chung Bookstore.

Wan, R.-J. (2005). *Hànyǔ zhèngyīn jiāochéng* [A lesson in the correct pronunciation of Chinese]. Beijing: Peking University Press.

Yeh, T.-M. (1994). *Ten Lessons in Elementary Mandarin Chinese*. Taipei: World Chinese Language Association.

Appendix A

中文捲舌音聽力感知測驗

您好：

本人是國立中山大外國語文學系三年級學生，為了想了解中文母語人士對中文捲舌音的感知，於是設計了這一項測驗。由於您的實驗結果對本研究與將來相關議題的探討有重要的貢獻，希望您可以配合填答以下問題，謝謝！

除基本資料外，本測驗包含兩大部分，總計有三十六個填答項目，所需時間約五分鐘，而如何回答則會在以下各部份的填答說明中詳加解釋。此外，參與受試者的個人資料與結果皆僅供本實驗用途，不會洩漏，請放心填寫。最後，繳回此份問卷即表示您同意參與這項研究。

基本資料

性別：☐ 男 ☐ 女

第一部分

在第一部分的實驗裡，您將會聽到十八個中文單音詞，請試著判別其應該分別歸類在為「捲舌音組」或是「非捲舌音組」，在該組的☐中打勾。例如：

覺得聽到的是「ㄣㄩ」（像是「又」），則勾選「捲舌音組」；

覺得聽到的是「ㄣ」（像是「思」），則勾選「非捲舌音組」。

這些問題沒有絕對的答案，請依個人感覺判斷。

1	☐ 「捲舌音組」	☐ 「非捲舌音組」
2	☐ 「捲舌音組」	☐ 「非捲舌音組」
3	☐ 「捲舌音組」	☐ 「非捲舌音組」
4	☐ 「捲舌音組」	☐ 「非捲舌音組」
5	☐ 「捲舌音組」	☐ 「非捲舌音組」
6	☐ 「捲舌音組」	☐ 「非捲舌音組」
7	☐ 「捲舌音組」	☐ 「非捲舌音組」
8	☐ 「捲舌音組」	☐ 「非捲舌音組」
9	☐ 「捲舌音組」	☐ 「非捲舌音組」
10	☐ 「捲舌音組」	☐ 「非捲舌音組」
11	☐ 「捲舌音組」	☐ 「非捲舌音組」
12	☐ 「捲舌音組」	☐ 「非捲舌音組」
13	☐ 「捲舌音組」	☐ 「非捲舌音組」
14	☐ 「捲舌音組」	☐ 「非捲舌音組」

15	☐ 「捲舌音組」	☐ 「非捲舌音組」
16	☐ 「捲舌音組」	☐ 「非捲舌音組」
17	☐ 「捲舌音組」	☐ 「非捲舌音組」
18	☐ 「捲舌音組」	☐ 「非捲舌音組」

第二部分

在第二部分的實驗裡，您會聽到十八個中文單音詞，請依「捲舌的強度或有無」給聽到的單音詞 1 到 5 評分，然後在給予的分數 ☐ 中打勾。例如：

若是覺得聽到的是「完全不捲舌」的「ㄖ」，則給予其 1 分；

若是覺得聽到的是「稍為有捲舌」的「ㄕ」(也可能像「ㄖ」)，可給予其 3 分；

若是覺得聽到的是「明顯、強捲舌」的「ㄕ」，可給予其 5 分。

這些問題依舊沒有絕對的答案，可以依個人感覺給分。

	無捲舌 ←—————→ 強捲舌				
1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
3	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
4	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
5	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
6	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
7	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
8	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
9	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
10	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
11	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
12	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
13	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
14	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
15	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
16	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
17	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
18	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

測驗結束，感謝您的填答！若對實驗結果感興趣，可透過以下 E-mail 連絡本人：
y9024131@yahoo.com.tw

Appendix B

Mandarin Retroflexes Perception Test

Dear participants,

I am a junior student in the Department of Foreign Languages and Literature of National Sun Yat-sen University. In order to understand how Mandarin speakers would perceive Mandarin retroflexes, I designed this test. Since your responses will contribute significantly to my research and future studies on this issue, I hope that you can cooperate and answer the following questions. Thank you!

With “Demographic Information” excluded, the test contains two parts, in which there are 36 questions in total. The whole test is expected to take 5 minutes, and the way to answer the questions will be described in more detail in the instruction of each part. Besides, your personal information and responses will be used only for my research and held in strict confidence. Please feel assured in answering the questions. Finally, the return of this answering sheet is your consent for participation in this research.

Demographic Information

Sex : ☐ Male ☐ Female

Part I

In Part I, you will hear 18 Mandarin monosyllabic words. Please try to categorize each of the words into “retroflex” group or “non-retroflex” group and check the box of the group you choose. For example,

If you think you hear a ‘cha,’ then choose the “retroflex” group;

If you think you hear a ‘s(u),’ then choose the “non-retroflex” group.

There are no absolutely right or wrong answers to the questions. Please make judgments based on your feeling.

1	☐ “Retroflex” group	☐ “Non-retroflex” group.
2	☐ “Retroflex” group	☐ “Non-retroflex” group.
3	☐ “Retroflex” group	☐ “Non-retroflex” group.
4	☐ “Retroflex” group	☐ “Non-retroflex” group.
5	☐ “Retroflex” group	☐ “Non-retroflex” group.

6	☐	“Retroflex” group	☐	“Non-retroflex” group.
7	☐	“Retroflex” group	☐	“Non-retroflex” group.
8	☐	“Retroflex” group	☐	“Non-retroflex” group.
9	☐	“Retroflex” group	☐	“Non-retroflex” group.
10	☐	“Retroflex” group	☐	“Non-retroflex” group.
11	☐	“Retroflex” group	☐	“Non-retroflex” group.
12	☐	“Retroflex” group	☐	“Non-retroflex” group.
13	☐	“Retroflex” group	☐	“Non-retroflex” group.
14	☐	“Retroflex” group	☐	“Non-retroflex” group.
15	☐	“Retroflex” group	☐	“Non-retroflex” group.
16	☐	“Retroflex” group	☐	“Non-retroflex” group.
17	☐	“Retroflex” group	☐	“Non-retroflex” group.
18	☐	“Retroflex” group	☐	“Non-retroflex” group.

Part II

In part II, you will hear 18 Mandarin monosyllabic words. Please give each word a score of 1 to 5 according to “the degree of perceived retroflexion” and check the box of the score you would like to give. For example,

If you think you hear a non-retroflex ‘z,’ then give it one point;

if you think you hear a slightly retroflexed ‘zh(u)’ (or it may sound like ‘z(u)’), you can give it 3 points;

if you think you hear a strongly retroflexed ‘zh (u),’ then you can give it 5 points.

Again, there are no absolutely right or wrong answers. Please give scores based on your feeling.

	Non-retroflex ←————→ Strongly retroflexed				
1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
2	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
3	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
4	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
5	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
6	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
7	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
8	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
9	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

10	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
11	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
12	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
13	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
14	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
15	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
16	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
17	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
18	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

This is the end of the test. Thank you very much for your participation! If you are interested in the results, you can contact me by this E-mail:

y9024131@yahoo.com.tw