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Acoustic Analysis of Mandarin Vowels Pronounced by Macao and Hong Kong Cantonese Speakers

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Abstract

This study compares the vowel production of Mandarin Chinese and Cantonese by Macao and Hong Kong Cantonese speakers. There are 5 volunteers of Macao native Cantonese speakers and 5 volunteers of Hong Kong native Cantonese speakers. The 10 Mandarin vowels and the 11 Cantonese vowels are pronounced by these groups. And there are 5 volunteers of native Mandarin speakers produce the same Mandarin vowels. All participants are female speakers. The acoustic vowel qualities of formant one (F1) and formant two (F2) values of these two languages were measured and analyzed. Result shows that Macao speakers have good performance on F1, the height of the tongue is closed to the F1 of Mandarin vowels. They can identify new vowels and pronounce Mandarin vowels more native-like than Hong Kong speakers as Hong Kong speakers adapted their native vowels to produce some Mandarin vowels.

Introduction

- Difference between Cantonese and Mandarin

Cantonese is a significant living language spoken by almost a hundred million people in southeastern part of China, including Hong Kong Special Administrative Region (HKSAR) and Macao Special Administrative Region (MSAR). Besides, it is spoken in Malaysia, Singapore, Europe, Australia, Fiji, North America and many other part of the world where the Cantonese people have settled. It is one of the family of Chinese languages and retains many more traces of its ancient roots than do most of the other languages. By comparison, Cantonese is a language which seems unafraid to adopt or adapt, notably from English in the past country or so, and it invents, evolves and discards slang at a frenetic rate. As a result it is a very rich language (Baker & Ho, 2006).

Mandarin or Mandarin Chinese was the way that the Western people referred to the language spoken by the officials or "mandarins" at the Imperial Court. It was then referred to the northern dialect, which is spoken by over 70% of the Chinese or Han people and has become the *lingua franca* for the whole of China. This official language is known as *Putonghua* "common speech" in China, which is now sometimes referred to in the West as Modern Standard Chinese although the term Mandarin still lingers on. Beijing (Peking) pronunciation is taken as the standard but there are many regional variations. *Putonghua* is taught in schools and used in universities and colleges all over China. *Putonghua* is known as *huayu* in overseas Chinese communities and as *guoyu* "national language" in Taiwan, all these names refer to the same language (Scurfield, 2003).

According to He (2006) (Mushangwe, 2010), it is necessary to have a strong background knowledge for sound system of Chinese languages when a foreign student wants to master Chinese language. In other words, the sound systems of Chinese languages are difficult to master due to the complexity of the vowel system and the phonological variations. The Canada and the World (2011) (Mushangwe, 2010) article states that Chinese language is one of the World's Hardest Languages as it is a vowel-rich language which uses tones to create numerous vowel sounds.

As a native Cantonese speaker, I found out that it is not difficult to acquire Mandarin and I can communicate with the people from Mainland, China without language barriers. This phenomenon also happens to Cantonese speaking region. People from Mainland, China claim that Macao people have better Mandarin pronunciations than the Hong Kong people. Thus, it brings my interest to look into the differences in production of Mandarin between Macao and Hong Kong people, by comparing their Cantonese and Mandarin vowels using vowel charts of both languages.

- Vowel inventories

-- Cantonese Vowel System

According to So & Wang (1996), there are eleven vowels in Cantonese, which follows the inventory proposed in Zee (1991) (So & Wang, 1996)in IPA[1]: long vowels are [i] [e] [ɔ] [ɐ] [u] [ʊ] [1] while short vowels are [y] [ɛ] [œ] [a]; in SAMPA[2] are represented as [i] [y] [e] [E] [O] [9] [6] [a] [u] [U] [I] respectively. The vowel description of Cantonese is shown in Table 1.

IPA	SAMPA	Vowels Description[3]
[i]	[i]	Close front unrounded vowel
[y]	[y]	Close front rounded vowel
[e]	[e]	Close-mid front unrounded vowel
[ɛ]	[E]	Open-mid front unrounded
[ɔ]	[O]	Open-mid back rounded
[œ]	[9]	Open-mid front rounded
[ɐ]	[6]	Open schwa (turned a)
[a]	[a]	Open front unrounded vowel
[u]	[u]	Close back rounded vowel
[ʊ]	[U]	Near-close near-back rounded vowel (lax u)
[ɪ]	[I]	Near-close near-front unrounded vowel (lax i)

Table 1. Cantonese vowels transcription in IPA and SAMPA and description

-- Mandarin Vowel System

According to Meng, Chen & Li (2006), the 10 vowels in Mandarin in IPA are [i] [u] [y] [o] [ɤ] [a] [ɿ] [ʅ] [ə] [ɛ], in which in SAMPA is represented as [i] [u] [y] [o] [7] [a] [I\] [1] [@] [E]. The Mandarin vowels can be divided into three levels of height: high, mid and low, which gives a systematic entry-point to tackle the Mandarin vowel system. The vowel description of Mandarin is shown in Table 2.

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[1] IPA: International Phonetic Alphabeth is a construction of language-independent phonemic alphabets which consists of a huge set of symbols for phonemes, suprasegmentals, tones/word accent contours, and diacritics. IPA alphabet quite unsuitable for computers which usually requires standard ASCII as input.

[2] SAMPA: Speech Assessment Methods - Phonetic Alphabet is designed to map IPA symbols to 7-bit printable ASCII characters. In SAMPA system, the alphabets for each language are designed individually. The objective is to make it possible to produce a machine-readable phonetic transcription for every known human language

[3] Source from www.phon.ucl.ac.uk/home/sampa/x-sampa.htm#vowels and http://en.wikipedia.org/wiki/X-SAMPA

IPA	SAMPA	Vowels Description[4]
[i]	[i]	Close front unrounded vowel
[u]	[u]	Close back rounded vowel
[y]	[y]	Close front rounded vowel
[o]	[o]	Close-mid back rounded vowel
[ɤ]	[7]	Close-mid back unrounded
[a]	[a]	Open front unrounded vowel
[ɿ]	[I\]	Near-close central unrounded vowel
[ʅ]	[1]	Close central unrounded
[ə]	[@]	Schwa
[ɛ]	[E]	open-mid front unrounded

Table 2. Mandarin vowels transcription in IPA and SAMPA and description

- Formant frequencies: F1 and F2

According to Kent and Read (2002), vowels are the simplest sounds to analyze and describe acoustically. It can be indefinitely prolonged as an articulatory or acoustic phenomenon. There is no need to consider the time dimension beyond choosing an instant that is taken as representative of the vowel production. Vowels often have been characterized with the frequencies of the first three formants. Thus, a given vowel could be represented as a single point in a three-dimensional space defined by the F1, F2 and F3 frequencies.

Kent and Read (2002) state formant frequencies must be adjusted for speaker age and gender, and it also appears that formant frequencies may vary across languages for the same nominal IPA vowel.

A formant is a concentration of acoustic energy around a particular frequency in the speech wave which can be observed at periodic and aperiodic waves. There are several formants, each of them correspond to resonances in the vocal tract.

Each vowel has a clear formant structure, and simply can be defined with first formant (F1) frequency and second formant (F2) frequency. Vowel that can be distinguished from one another is by the differences in these overtones.

In this thesis, only the first formant and the second formant are discussed.

- F1 in vowels is inversely related to vowel height (tongue height), i.e. the higher the value, the lower the vowel height, and vice versa. It is the strongest formant and tends to be highly associated with judgments of loudness.

- F2 in vowels is related to the degree of tongue position, i.e. the more front the vowel, the higher the second formant, and vice versa.[5]

[4] Source from www.phon.ucl.ac.uk/home/sampa/x-sampa.htm#vowels and http://en.wikipedia.org/wiki/X-SAMPA

The formant values also observe from a learner could be the basis to evaluate whether the learner is making the progress in pronunciation. Thus, by measuring the F1 and F2 frequency values, the vowel height and the place of articulation of vowels can be analysed. With these two frequency values, a simplist formant charts, that is, a graphic representation of vowel space, can be made, in which F1 as y-axis while F2 as x-axis. This representation is equivalent to articulatory vowel charts in the acoustic domain. (So & Wang, 1996).

-- F1 and F2 reference data for Cantonese vowels

The below data which is based on the Hong Kong spoken Cantonese database is from So & Wang (1996) as a standard reference in this thesis.

SAMPA	6	9	a	e	E	i	I	O	u	U	y
F1 (Hz)	919	615	770	434	550	389	444	680	738	733	544
F2 (Hz)	1516	1318	1436	929	976	2600	2097	1568	2046	1064	2009

Table 3. F1 and F2 values of Cantonese vowels in SAMPA

-- F1 and F2 reference data for Mandarin vowels

The below data is from Meng, Chen & Li (2006) as a standard reference in this thesis.

SAMPA (Common vowels with Cantonese)	a	E	i	u	y
F1 (Hz)	952	856	311	354	305
F2 (Hz)	1371	2119	2871	762	2411
SAMPA (New vowels to Cantonese)	1	7	@	I\	o
F1 (Hz)	416	622	656	399	654
F2 (Hz)	2092	1334	1370	1762	947

Table 4. F1 and F2 values of Mandarin vowels in SAMPA

Relevant fact

- Vowels

Vowels are voiced sounds which are produced with the vocal cords in vibration. They are pronounced with opened mouth, no contact between the tongue and the top of the mouth or teeth and no obstruction to the flow of air. Their amplitudes are higher, more stable and easier to analyze and describe acoustically.

Articulatory description of vowels is divided into different categories based on the length of the sound, position of the tongue and shape of the lips. For instance, if a vowel is described as close front, it means that the tongue and the top of the mouth is close in

[5] From http://ec-concord.ied.edu.hk/phonetics_and_phonology/wordpress/learning_website/suggested_answers.htm#Chapter_2

distance and the front part of the tongue is raised by the speaker when pronounce that vowel.

- Bilingualism and second-language learning

Research in bilingualism and second-language learning suggested that there is an interaction between L1 and L2 of a speaker. The direction and strength of this interaction is assumed to be the influence of the number and nature of phonological categories established for two languages, the amount each language is used, the circumstances for language use, and the dominance language of the speakers (MacLeod, et al., 2009; Flege, 1999).

Flege (1995) proposed Speech Learning Model (SLM) which was developed to account for age-related limits on second-language pronunciation among bilingual speakers who have spoken their second-language for many years. This model provides specific hypotheses regarding the interaction between the first and second languages spoken by bilinguals. Rallo and Romero (2012) said SLM makes the assumption that the ability to perceive and produce L2 or non-native speech sounds is not lost in late adolescence or adulthood. Late learners can perceive and produce the target sounds with varying degrees of success, depending on the nature and conditions of L2 exposure and use. It claims that the sound system of L1 and L2 exist in a common phonological space and influence each other. According to the SLM, to achieve native-like production in a second language, a speaker (1) must have an accurate understanding of the properties that differentiate this language's phonemes from one another, and from phonemes in the speakers first language; (2) must store and structure this information in long-term memory; and (3) must learn the articulations required to reliably and accurately produce the sounds of the second language. In cases where differences between phonemes in the two languages are minimal, adult learners are hypothesized to use equivalence classification to relate sounds from the second language to their own first language categories. In cases where a large difference exists between phonemes of the two languages, the speaker can create a new category for the new phoneme; however, the ability to create new categories decreases with age.

Flege et al. (2003) used the Equivalence Classification Hypothesis to analyses the vowel productions by the late bilinguals. This hypothesis predicts that bilinguals will produce monolingual-like phonemic vowel contrasts in their L1, but that their L2 vowels will have values similar to those in their L1. It is assumed that bilinguals have classified L2 vowels in terms of similar L1 vowels, and thus their production of L2 vowels will not be significantly different from their L1 vowels.

One of the approaches by Strange (2007) (MacLeod et al., 2009) is a comparison of the acoustically analyzed productions from monolingual and bilingual speakers, provides a basis for comparing productions of L2 speakers to native speakers, and gives a description of similarities and differences between the groups of speakers (Baker & Trofimovich, 2005; Guion, 2003).

Sundara and Polka (2008) suggest that bilinguals like to have merged categories for similar phonemes. Then in this paper, it is possible that the bilinguals show a merger in the vowels of the L2 has assimilation to their L1 vowels.

The Bilingual Category Hypothesis predicts a bi-directional influence between the L1 and L2, such that the vowels produced in the L1 and L2 will be significantly different from the vowels of monolingual speakers of the two languages. Hence, the interaction between L1 and L2 vowels in the pronunciation of the bilingual speakers will be analyzed. Although the bilingual participants may form separate categories for similar phonemes across the two languages, those categories may not be identical to those of monolingual speakers. As Guion (2003) assumed that bilinguals may produce vowels that are significantly different from monolinguals, but also significantly different across the two languages. In his study showed that the early Quichua–Spanish bilinguals tended to produce vowels that were different from those of monolingual speakers of either language.

Vowel production accuracy may vary among individuals who began learning their L2 in adulthood. It was examined that vowels spoken by students in Brazil whose overall pronunciation of English was relatively good or poor (Flege et al. 1997; Major (1987). Any two languages being compared might differ in terms of the number of contrastive vowels they possess (Flege et al. 1997; Maddieson, 1984), adult beginners usually interpret L2 vowels as instances of the closest L1 vowel, and produce them accordingly.

L1 and L2 vowels are related perceptually to one another thus provides an important determinant of how inexperienced adults learners will produce L2 vowels. However, if L2 learners establish new phonetic categories for certain L2 vowels (Flege, 1997), the perceived relation between L1 and L2 vowels may change during L2 acquisition. Such changes in perception may, in turn, engender changes in vowel production.

Researchers have used a variety of techniques to infer how the vowels in two languages are related perceptually. L2 vowels represented by phonetic symbols not used to transcribe any L1 vowel have been classified as “new.” L2 vowels represented by the same symbol as that used for some L1 vowel have been classified as “identical” or “similar” (Flege, 1997; Flege, 1988). It has been hypothesized that adult learners will ultimately produce new L2 vowels more accurately than similar L2 vowels because they are more likely to establish additional phonetic categories for new vowels. Thus, it means that there are “new” vowels produced when Cantonese speakers pronounce Mandarin vowels [l\] [7] [@] [1] [o] in SAMPA, and they produce “identical” or “similar” vowels when they pronounce Mandarin vowels [i] [u] [y] [a] [E].

- Related research

Result of Meng, Zee and Lee’s (2007) comparison between the vowel charts in Cantonese and English shows the common mispronunciations due to English vowels /e, æ, o, ɚ, ʌ, a/ that are missing in the Cantonese phonetic inventory. Hence when Cantonese native speakers enunciate these English vowels, they replace with Cantonese vowels that are close in terms of production and perception. Depending on the degree of resemblance, a subset of these vowels may be perceived as mispronunciations, due to prominent transfer effects from Cantonese (L1) to English (L2).

MacLeod et al. (2009) investigate of the acoustic-phonetic differences between Canadian English and Canadian French and to the understanding of acoustic-phonetic abilities of early bilingual speakers, whether they can achieve native-like production of vowels that are similar in two languages. The results contradict to the investigations of late bilinguals, whose vowel productions exhibited influences of the phonemic categories of their first language. The study of adult bilinguals has tended to focus on adults who acquired their second language during late childhood or later; these late bilinguals have been found to produce phonemes in their second language that are influenced by phonemic categories in their first language. The study also investigates the acoustic-phonetic productions of bilinguals in their two languages, thus permitting the exploration of interactions between the two languages and the question of ultimate attainment for the production of vowels by bilinguals. The authors propose the late bilinguals have not created a new category for the English /e/ and thus tend to produce a more monophthongal mid- front vowel, which may resemble the Italian vowel. And they conclude that it was not possible to assess the impact of the second language on the native language of speakers.

The findings from Guion (2003) underline the importance of studying productions in both languages to achieve a full understanding of the bilingual vowel system. Flege et al. (2003) focused on a single vowel produced in the bilinguals' second language, results indicate that the age of second-language learning can influence speakers' ability to produce vowels in a native-like manner. Result of Oh et al. (2011) suggests that L2 vowel production is affected importantly by age of acquisition and that there is a dynamic interaction, whereby the L1 and L2 vowels affect each other. The study of Flege et al. (1997) provided evidence that adults who learn a second language (L2) will come to produce and perceive certain vowels in their L2 more accurately as they gain experience in the L2.

- Macao and Hong Kong Cantonese

There are differences in educational background in Macao and Hong Kong in the past. Macao was a Portuguese colony while HK was a British colony. It was necessary to learn English, while in Macao was not. Therefore, I would like to investigate if there's a different in pronunciation of Mandarin vowels between Macao and Hong Kong people and which group of people has a more native-like pronunciation of Mandarin vowels.

Besides, Cantonese is an official language in Macao and Hong Kong, and is widely spoken and carries forward in these two regions. It is said to be authentic or standard Cantonese. However, there is not yet any research to compare the acoustic vowels between Cantonese and Mandarin language. Thus, in this thesis, I focus on the acoustic vowels production between these two languages by Macao and Hong Kong speakers.

Research Questions

1. Do Cantonese vowels act as an advantage for the native Cantonese speakers to learn Mandarin?

2. Are the Mandarin vowels produced by Mandarin monolinguals and Cantonese bilinguals different in mean F1 and mean F2? What are the acoustic differences between them?

3. Which Mandarin vowels are likely to be more problematic for a Cantonese speaker in Mandarin vowel production? To what extent are Cantonese speakers interfered by their mother tongue while producing Mandarin vowels?

4. How do the Cantonese and Mandarin bilinguals organize their two language systems to allow interaction of phonological categories, instead of a merger?

Hypotheses

1. It is assumed that the pronunciation of Mandarin vowels is from the perception of the rich Cantonese vowels, indicates that Cantonese vowels act as an advantage for the native Cantonese speakers to learn Mandarin as the numbers of Cantonese vowels are more than the Mandarin vowels. By comparing the two vowel systems, there are 5 vowels in common: [i] [u] [y] [a] [E] in SAMPA. It is expected that the pronunciation of theses vowels by Cantonese speakers is similar to those 5 Mandarin vowels.

2. The Mandarin vowels produced by Mandarin monolinguals and Cantonese bilinguals are slightly different in mean F1 and mean F2 as the native Cantonese speakers adapt the Cantonese vowels to the production of Mandarin vowels, thus, it is expected that there are differences with the vowels and the mean F1 and F2 will be different as the bilinguals have perceptions of L1 and L2 vowels.

3. [l\] [7] [@] [1] [o] in SAMPA in Mandarin do not exist in the Cantonese vowel system and [9] [e] [O] [U] [6] [I] in SAMPA in Cantonese do not exist in Mandarin vowel system. Among them, Cantonese [U] [O] are similar to the Mandarin [o] of the Mandarin-speaking monolinguals, and Cantonese [9] [e] are similar to the Mandarin [@] of the Mandarin-speaking monolinguals. Thus, it is predicted that the Cantonese speakers adapt those vowels in their systems to pronounce a similar vowel in Mandarin or produce new vowels.

4. According to MacLeod et. al., (2009), it was indicated that bilinguals formed two separate categories between the two languages for similar vowels in order to produce

monolingual-like values. Thus, it is predicted that the Cantonese and Mandarin bilingual speakers were assessed in the two languages so as to allow the exploration of interactions between these two languages.

Methodology

In order to investigate whether the Macao people has a more approximate pronunciation of Mandarin vowels than the Hong Kong people, an experiment is carried out by recording the sound of single words in Cantonese and Mandarin pronounced by three groups of female participants.

- Speakers

Three groups of female volunteers whose ages are ranged from 21 to 24 years old were chosen to carry out the experiment. The reasons to choose female adult speakers are: (1) differences in oral structures between female and male; (2) to generate normal frequencies as female frequencies are comparatively higher than the male frequencies; (3) the standard level of knowledge of Chinese characters learning at the stage of learning with the education level. There are 5 participants in each group: the native Cantonese speakers from Macao who are university students from University of Macao; the native Cantonese speakers from Hong Kong who are university students from different universities in Hong Kong; and the native Mandarin speakers are from University of Pompeu Fabra.

- Materials

As mentioned in Introduction, there are 11 Cantonese vowels in SAMPA: [i] [y] [e] [E] [O] [9] [6] [a] [u] [U] [I] and 10 Mandarin vowels in SAMPA: as [i] [u] [y] [o] [7] [a] [I\] [1] [@] [E] are selected to be examined in the experiment.

For every vowel, 5 Chinese traditional characters which contain the same vowel were chosen, that is, each vowel will be allocated with different consonants in order to make a sound that has a meaning and can be pronounced. In total, 55 Chinese traditional characters for the Cantonese vowels and 50 Chinese traditional characters for the Mandarin vowels were selected (see appendix: Lists of traditional Chinese characters with Monophthongs and Transcriptions in Cantonese and Mandarin).

Participants used microphones to record the sound in the computers. They record the sound in a silent room. All recordings are in WAV files.

- Procedures

Both native Cantonese speakers of Macao and Hong Kong had to record both the sound of Cantonese and Mandarin characters from the lists, while the native Mandarin speakers had to record the sound of Mandarin characters only. Each sound of the characters was recorded 2 times by the speakers.

As a result, there are 110 Cantonese vowels per recording and 100 Mandarin vowels per recording for each native Cantonese speaker and 100 Mandarin vowels per recording for each native Mandarin speaker were obtained.

The Cantonese vowels pronounced are considered as control experiment while the Mandarin vowels pronounced by the Cantonese speakers are used for further investigation. The Mandarin vowels pronounced by the native Mandarin speakers are also being recognized as a control experiment so as to compare with the Mandarin vowels pronounced by the native Cantonese speakers.

Since the Mandarin speakers are required to speak the vowels independently and it is really too difficult to speak the monophthongs independently, then they can speak the Mandarin character with the monophthong as the final. The monophthong was then cut from the sound of the character in signal processing (Meng, Chen & Li 2006)

The recordings of Mandarin speakers were recorded here in Spain while the recordings of Cantonese speakers were recorded in MSAR and HKSAR with instructions given. That is, the speakers had to record the sound of the Chinese words in Mandarin and Cantonese and save it in a WAV file. Each word was repeated two times clearly and slowly and was recorded in a silent and without echo environment.

- Acoustic measurements

In order to identify and analyze the vowels, the F1 and F2 of the sound waves were measured using Praat (can be downloaded from http://www.fon.hum.uva.nl/praat/) which was used to annotate all the recordings obtained from the speakers. Firstly, the recordings were transferred onto a computer to be analyzed. Each vowel of the characters was annotated manually in Praat so that the allophones of the vowels could be obtained (since SAMPA can be read and understood by Praat, all the "phonetic symbols" used are in SAMPA instead of IPA).

After the annotation of the vowels, a Praat script created by Mietta Liennes[6] was used to elicit a file which contains the results of the formants of vowels with corresponding speakers in Praat. The file elicited by the script presents the filename, segment label and the formants of F1, F2 and F3 in Hz of all the recordings. This Praat scripts runs the set of Praat commands written using a scripting language specific of Praat in a text file.

The file is then loaded in Microsoft Excel, a column "Language" is added to identify the languages of the corresponding groups of participants. The names of the Excel table is shown below as an example:

Filename	Language	Segment label	F1 (Hz)	F2 (Hz)	F3 (Hz)

According to Flege, Bohn, and Jang (1997), a technique used to measure how L1 and L2 vowels are related perceptually is to plot the F1 and F2 measurements in a two-

[6] Downloaded from http://www.helsinki.fi/~lennes/praat-scripts/

dimensional space. Thus, only the F1 and F2 formants are used for the analysis. Mean values for F1 and F2 formants of each vowel of the corresponding groups of participants were obtained. All the mean F1 and F2 formant values of each group were rounded up to the nearest whole number and input to a new Excel file. According to MacLeod, et. al. (2009), x-axis is the log-mean normalized values for F2; on the y-axis is the log-mean normalized values for F1. Thus, with F1 as y-axis and F2 as x-axis, 5 formant charts were created to present the allocation of vowels of Mandarin and Cantonese produced by the three groups of speakers.

- Data Analysis

Since the formant frequencies showed little differences across the two repetitions, in order to obtain a more accurate result, the overall mean values of each group of speakers were used in all formant analyses. Thus, there are 2600 vowels in total to be analyzed (Cantonese vowels: 11 vowels x 5 words per vowel x 2 times pronunciations per vowel x 10 native Cantonese speakers + Mandarin vowels: 10 vowels x 5 words per vowel x 2 times pronunciations per vowel x 15 speakers).

As the goal of this study was to analyse differences in vowel production across groups, the formant values observed from the speakers were used to evaluate their pronunciation during the progress, that is, the scope of the analysis to F1 and F2 is sufficient to capture differences in height and advancement that contrast the high vowels targeted in this study.

Later, the 5 formant charts obtained were used to compare and find out the differences and similarities of vowels in both languages from each group of participants. The plotted vowel chart positions show evidence of Cantonese speakers' pronunciation in comparison with the Mandarin pronunciation. Firstly, the results of the native languages were used to compare with their standard native languages accordingly in order to examine if the data are valid. Secondly, the Mandarin formant charts of Macao and Hong Kong speakers were compared with the Mandarin formant chart of Mandarin speakers. As there are slightly differences in vowel production between speakers due to the different oral structures of each speaker, only the big differences in the position of the same vowel in the Mandarin formant charts are chosen to compare with the Cantonese formant charts of the corresponding language group. As a result, the Mandarin vowels production of Macao and Hong Kong speakers can be analyzed and the way of vowel pronunciation can be investigated. It is used to find out whether there are vowels that match the Cantonese formant charts or Mandarin formants.

Results

Results from the experiments are show in the following five graphs and five tables respectively. Numbers of data are round up to whole numbers.

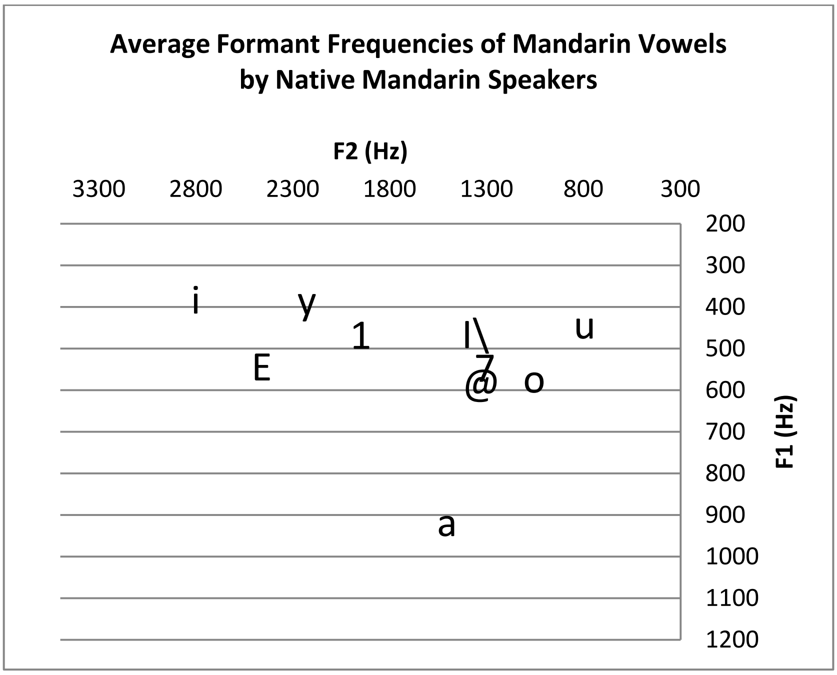

Figure 1. Native Mandarin Formant Chart

SAMPA (Common vowels with Cantonese)	a	E	i	u	y
F1 (Hz)	915	541	380	440	381
F2 (Hz)	1504	2460	2800	795	2228
SAMPA (New vowels to Cantonese)	1	7	@	I\	o
F1 (Hz)	465	544	581	463	570
F2 (Hz)	1949	1309	1327	1358	1055

Table 5. Native Mandarin Mean Values of Vowel Formants

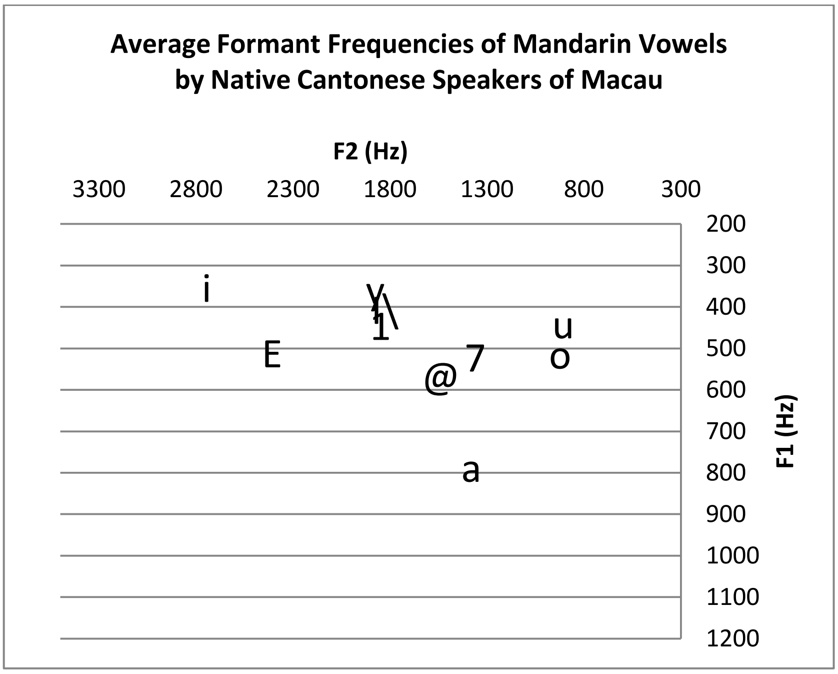

Figure 2. Macao Mandarin Formant Chart

SAMPA (Common vowels with Cantonese)	a	E	i	u	y
F1 (Hz)	786	510	352	440	357
F2 (Hz)	1380	2407	2744	907	1876
SAMPA (New vowels to Cantonese)	1	7	@	I\	o
F1 (Hz)	444	520	566	405	513
F2 (Hz)	1849	1360	1537	1826	923

Table 6. Macao Mandarin Mean Value of Vowel Formants

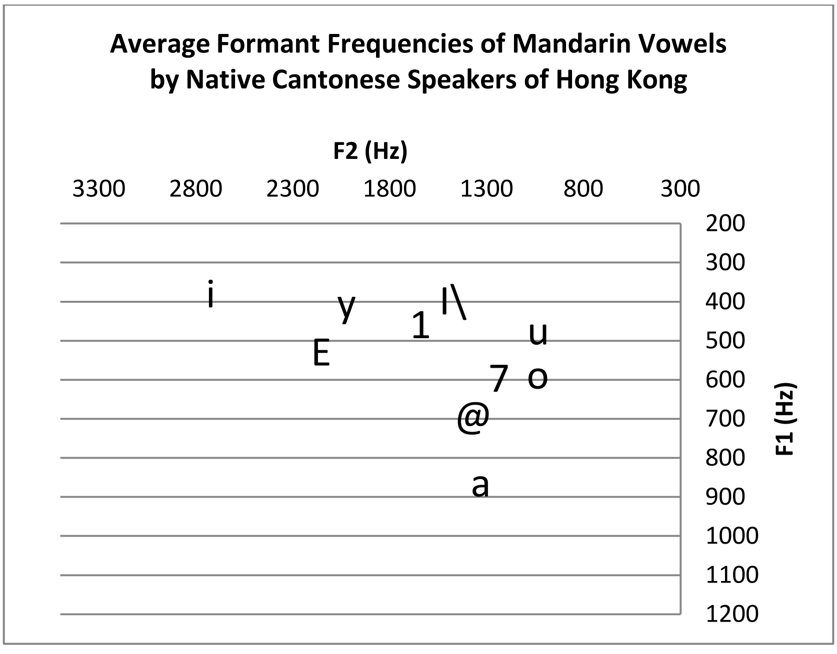

Figure 3. HK Mandarin Formant Chart

SAMPA (Common vowels with Cantonese)	a	E	i	u	y
F1 (Hz)	861	526	377	472	401
F2 (Hz)	1330	2153	2723	1034	2023
SAMPA (New vowels to Cantonese)	1	7	@	I\	o
F1 (Hz)	456	593	690	395	585
F2 (Hz)	1641	1236	1368	1474	1036

Table 7. HK Mandarin Mean Value of Vowel Formants

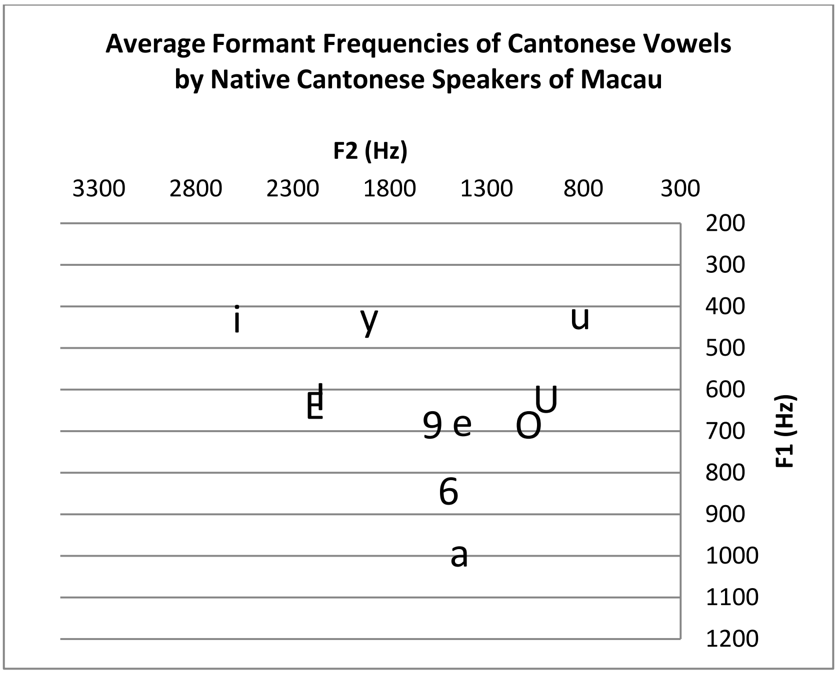

Figure 4. Macao Cantonese Formant Chart

	6	9	a	e	E	i	I	O	u	U	y
F1	841	682	990	676	635	427	614	682	419	620	422
F2	1496	1578	1439	1425	2187	2587	2157	1083	818	992	1906

Table 8. Macao Cantonese Mean Value of Vowel Formants

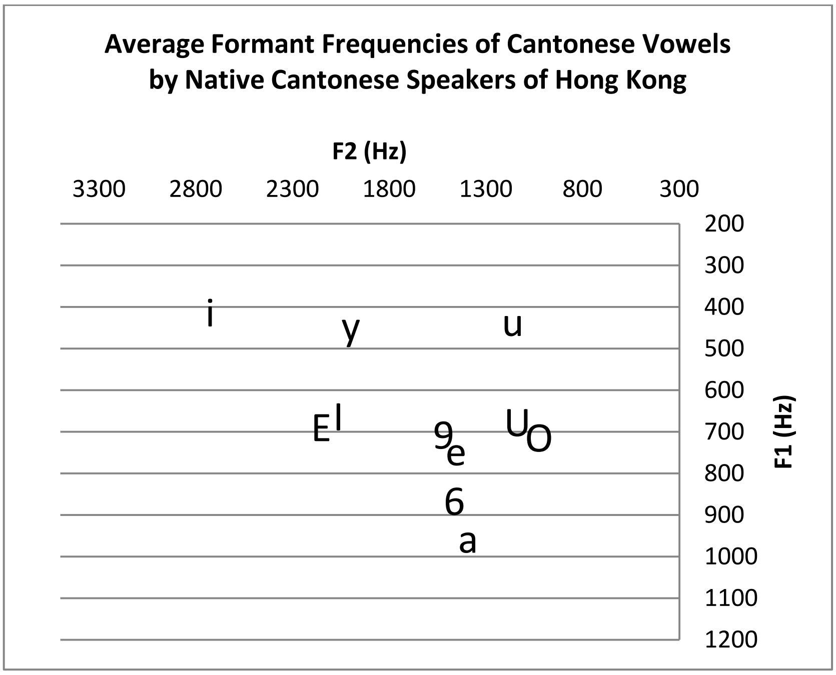

Figure 5. HK Cantonese Formant Chart

	6	9	a	e	E	i	I	O	u	U	y
F1	864	705	955	745	687	411	661	712	434	675	443
F2	1463	1518	1390	1453	2151	2725	2061	1024	1160	1137	1997

Table 9. HK Cantonese Mean Value of Vowel Formants

- Comparison between experimental and standard Mandarin vowels of native speakers

By comparing the data in Table 4 and Table 5, there are three vowels, [E], [y] and [I\] that show big differences in F1 and F2. For [E], there are 315Hz of difference in F1 and 341Hz in F2, it is expected that the tongue of the speakers moved forward and higher. For [y], there are 76Hz difference in F1 and 183Hz in F2, it is expected that the tongue of the speakers moved backward. For [I\], there are 64Hz difference in F1 and 404Hz in F2, it is expected that the tongue of the speakers moved backward.

- Comparison between experimental and standard Cantonese vowels of native speakers from Macao

As shown in Table 3 and Table 8, vowels [9], [a], [e], [E], [I], [O] and [u] show big differences in F1 and F2. For [9], there are 67Hz difference in F1 and 260Hz in F2, it is expected that the tongue of the speakers moved forward. For [a], there are 220Hz difference in F1 and 3Hz in F2, it is expected that the tongue of the speakers moved lower. For [e], there are 242Hz difference in F1 and 496Hz in F2, it is expected that the tongue of the speakers moved forward and lower. For [E], there are 85Hz difference in F1 and 1211Hz in F2, it is expected that the tongue of the speakers moved much forward. For [I], there are 170Hz difference in F1 and 60Hz in F2, it is expected that the tongue of the speakers moved lower. For [O], there are 2Hz difference in F1 and 485Hz in F2, it is expected that the tongue of the speakers moved backward. For [u], there are 319Hz difference in F1 and 1228Hz in F2, it is expected that the tongue of the speakers moved higher and much backward.

- Comparison between experimental and standard Cantonese vowels of native speakers from Hong Kong

From Table 3 and Table 9, it appears that [9], [a], [e], [E], [I], [O] and [u] have big differences in F1 and F2. For [9], there are 90Hz difference in F1 and 200Hz in F2, it is expected that the tongue of the speakers moved forward. For [a], there are 185Hz difference in F1 and 46Hz in F2, it is expected that the tongue of the speakers moved lower. For [e], there are 311Hz difference in F1 and 524Hz in F2, it is expected that the tongue of the speakers moved forward and lower. For [E], there are 137Hz difference in F1 and 1175Hz in F2, it is expected that the tongue of the speakers moved much forward. For [I], there are 217Hz difference in F1 and 36Hz in F2, it is expected that the tongue of the speakers moved lower. For [O], there are 32Hz difference in F1 and 544Hz in F2, it is expected that the tongue of the speakers moved backward. For [u], there are 304Hz difference in F1 and 886Hz in F2, it is expected that the tongue of the speakers moved higher and much backward.

Since the data shown in standard Mandarin and Cantonese formant charts had included the average formant values of both male and female participants, the results of F1 and F2 values might be varied to the experimental formant charts as only female speakers are chosen in this experiment.

Discussion

Each speaker has different vocal structure, the frequencies are slightly different between speakers, thus, only the big differences between the Mandarin vowels and Cantonese vowels by the Cantonese speaker are discussed.

- Mandarin vowels between native Mandarin and Macao Cantonese speakers

Compared to the Mandarin vowels pronounced by native Mandarin speakers, the Mandarin vowels pronounced by native Cantonese speakers are quite different. Differences in F1 and F2 of Mandarin vowels between Mandarin and Cantonese speakers of Macao are shown in Table 10:

SAMPA (Common vowels with Cantonese)	a	E	i	u	y
F1 (Hz)	129	31	28	0	24
F2 (Hz)	124	53	56	-112	352
SAMPA (New vowels to Cantonese)	1	7	@	I\	o

F1 (Hz)	21	24	15	58	57
F2 (Hz)	100	-51	-210	-468	132

Table 10. Differences in F1 and F2 values of Mandarin vowels between Macao Cantonese and Mandarin speakers

For similar vowels, as shown in Table 10, for [a], there are 129Hz of difference in F1 and 124Hz in F2; it is expected that the tongue of the speaker moves backward and higher. For [E], there are 31Hz of difference in F1 and 53Hz in F2, which implies that there is not much difference in between. For [i], there are 28Hz of difference in F1 and 56Hz in F2, it is expected that the tongue of the speaker moves a little backward and higher. For [u], there are no difference in F1 and 112Hz in F2, it is expected that the tongue of the speaker moves forward. For [y], there are 24Hz difference in F1 and 352Hz in F2, it is expected that the tongue of the speaker moves much backward. It can be seen that those Macao speakers attempt to move their tongues more forward and higher in order to achieve the Mandarin vowels, except [u], the position of the tongue is a bit lower.

For the new vowels, as shown in Table 10, for [1], there are 21Hz difference in F1 and 100Hz in F2, it is expected that the tongue of the speaker moves a bit backward. For [7], there are 24Hz of difference in F1 and 51Hz in F2 which shows that there is no much difference in between. For [@], there are 15Hz of difference in F1 and 210Hz in F2; it is expected that the tongue of the speaker moves much forward. For [I\], there are 58Hz of difference in F1 and 468Hz in F2, it is expected that the tongue of the speaker moves much forward and a little higher. For [o], there are 57Hz difference in F1 and 132Hz in F2, it is expected that the tongue of the speaker moves backward and a little higher.

From the above discussion, Cantonese vowels [9] [6] [e] [U] [O] do not have any effect on the pronunciation of the Mandarin vowels, but Cantonese vowel [E] (F1: 635; F2: 2187) may have an effect. [I] (F1: 614 ; F2: 2157) may have an effect on the pronunciation of Mandarin vowel [E] (F1: 510 ; F2: 2407) as the F1 and F2 difference between these vowels are very similar, thus, it cannot be defined which of these two Cantonese vowels has an effect on Mandarin vowel [E]. Moreover, Mandarin vowel [7], a new vowel, is perfectly pronounced, as difference is very little. [@] from Cantonese speakers is a bit forward than the [@] from Mandarin speakers; [o] might have an influence from Cantonese vowel [u], as it pronounced more similar to vowel [u], for the rest of new vowels [1] [I\], the F1 and F2 frequencies of these vowels are similar, which means, Macao speakers are able to identify and produce Mandarin vowels than adapting Cantonese vowels in Mandarin production.

Generally, it shows that the Macao speakers can adjust the height of the tongue to pronounce the Mandarin vowels; however, the front and back position of the tongue is more difficult for them as there are big differences in the F2 Mandarin and Cantonese vowels.

- Mandarin vowels between native Mandarin and Hong Kong Cantonese speakers

By comparing with the Mandarin vowels pronounced by native Cantonese speaker of Hong Kong, results are different to the Macao speakers. Differences in F1 and F2 of Mandarin vowels between Mandarin and Cantonese speakers of Hong Kong are shown in Table 11:

SAMPA (Common vowels with Cantonese)	a	E	i	u	y
F1 (Hz)	54	15	3	-32	-20
F2 (Hz)	174	307	77	-239	205
SAMPA (New vowels to Cantonese)	1	7	@	I\	o
F1 (Hz)	9	-49	-109	68	-15
F2 (Hz)	308	73	-41	-116	19

Table 11. Differences in F1 and F2 values of Mandarin vowels between Hong Kong Cantonese and Mandarin speakers

For similar vowels, as shown in Table 11, for [a], there are 54Hz of difference in F1 and 174Hz in F2; it is expected that the tongue of the speaker moves backward and a little higher. For [E], there are 15Hz of difference in F1 and 307Hz in F2; it is expected that the tongue of the speaker moves much backward. For [i], there are 3Hz of difference in F1 and 77Hz in F2; it is expected that the tongue of the speaker moves a little backward. For [u], there are 32Hz of difference in F1 and 239Hz in F2; it is expected that the tongue of the speaker moves much forward. For [y], there are 20Hz of difference in F1 and 205Hz in F2; it is expected that the tongue of the speaker moves backward. It can be seen that Cantonese speakers attempt to move her tongue higher in order to achieve the Mandarin vowels, except [u], in which the position of the tongue is a bit lower.

For the new vowels, as shown from Table 11, for [1], there are 9Hz of difference in F1 and 308Hz in F2; it is expected that the tongue of the speaker moves much backward. For [7], there are 49Hz of difference in F1 and 73Hz in F2; it is expected that the tongue of the speaker moves a little backward and lower. For [@], there are 109Hz of difference in F1 and 41Hz in F2; it is expected that the tongue of the speaker moves a bit forward and lower. For [I\], there are 68Hz of difference in F1 and 116Hz in F2; it is expected that the tongue of the speaker moves a little forward and higher. For [o], there are 15Hz of difference in F1 and 19Hz in F2 which means that there is no much difference in between.

From the above discussion, Cantonese vowels [I] [6] [e] [O] do not have any effect on the pronunciation of the Mandarin vowels. However, Cantonese vowel [U] (F1: 675 ; F2: 1137) may have an effect on the pronunciation of Mandarin vowel [7] (F1: 593 ; F2: 1236), the F1 and F2 difference between these vowels are 82Hz and 99Hz respectively; another one is Cantonese vowel [9] (F1: 705 ; F2: 1518) may have an effect on the pronunciation of Mandarin vowel [@] (F1: 690 ; F2: 1368), the F1 and F2 difference between these vowels are 15Hz and 150Hz respectively. Furthermore, it can be seen that Cantonese speaker cannot identify Mandarin vowels [1] [y] [I\], as the F1 and F2 frequencies of these vowels are similar. Mandarin vowel [7] is perfectly pronounced, however, for Hong Kong Cantonese speakers, [@] maybe is confused with [7] as comparatively, [@] is a bit forward and lower to the native [@]. Vowel [o] is considered as a new vowel and Hong Kong speakers pronounced it perfectly. Also, [1] [I\] are new vowels but Hong Kong speakers cannot pronounce perfectly, their tongue positions are different.

Generally, it shows that when Hong Kong speakers pronounced the common vowels, the front and back position of their tongues are a bit difficult for them as there are big differences in the F2 Mandarin and Cantonese vowels. For the rest of the Mandarin vowels, they try to adapt the Cantonese vowel to those vowels or try to make new vowels in order to pronounce more native-like. That is Hong Kong speakers cannot identify Mandarin vowels and try to adapt Cantonese vowels in mandarin production.

By looking at the results of Mandarin vowels pronounced by both native Cantonese speakers of Macao and Hong Kong, both groups show different extremes. It seems that Cantonese vowels do not have much effect on the Mandarin vowel production for Macao speakers as they can identify new vowels easily. Most new vowels pronounced by the Macao speakers reflect that they are capable to identify the new vowels instead of adapting native vowels. Results show that Mandarin vowels of F1 by Macao speakers are similar to that by Mandarin speaker, which means that they have mastered the height of the tongue position, but not the front and back of the tongue position as their F2 shows some differences; as a result, they cannot pronounce correctly some Mandarin vowels. For Hong Kong speakers, they cannot identify new vowels easily and tried to adapt their native vowels to pronounce the Mandarin vowels. Results on Hong Kong speakers show that Cantonese vowels have an effect on the pronunciation of the Mandarin vowels, there are differences in the F2 of common vowels of Mandarin and Cantonese; apart from that, results show that they try to adapt the Cantonese vowels for the rest of the Mandarin vowels to have a native-like pronunciation. Both the Macao and Hong Kong speakers have in common to use their own vowel systems to pronounce Mandarin vowels, which is to move their tongues in a higher position.

Results do show that the vowel production of Macao and Hong Kong people are different and match the hypotheses. The pronunciation of common vowels [i] [u] [y] [a] [E] by Cantonese speakers is similar to the corresponding Mandarin vowels. The vowels and the mean F1 and F2 values are different as the Cantonese speakers have perceptions of L1 and L2 vowels. Besides, it shows that Cantonese speakers of Macao are more able to assess in both Cantonese and Mandarin. Thus, Macao speakers are closer to the native Mandarin model in a sense that they pronounce as more native Mandarin speakers.

Conclusion

This paper analyses the Mandarin vowel production by native Cantonese speakers of Macao and Hong Kong in comparison of the native Mandarin speakers to investigate which group of Cantonese speakers produces more native-like Mandarin vowels. Results show that Macao speakers can identify new vowels and pronounce Mandarin vowels more natively than Hong Kong speakers. In this thesis, only the F1 and F2 values of bilingual speakers are considered, therefore, there might inaccurate results with the date as the year of learning for the speakers has not been controlled. Also, the recording environment and the target speakers might result in different variations. In the future research, it will be better to increase the number of speakers in each group and set limitations, such as year of learning and the age of speakers, to have a more accurate result.

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General proposal for the X- SAMPA transcription of vowels of the IPA symbols:
http://www.phon.ucl.ac.uk/home/sampa/x-sampa.htm#vowels

Vowels
http://ec-concord.ied.edu.hk/phonetics_and_phonology/wordpress/learning_website/suggested_answers.htm#Chapter_2

SpeCT - The Speech Corpus Toolkit for Praat
http://www.helsinki.fi/~lennes/praat-scripts/

X-SAMPA
http://en.wikipedia.org/wiki/X-SAMPA

Appendix

Lists of traditional Chinese characters for experiments:

No.	Traditional Chinese Characters with Monophthongs and Transcriptions in Mandarin (English meaning of words are in brackets)					SAMPA
1	衣 Yī (cloth)	逼 Bī (forcé)	雞 Jī (chicken)	批 Pī (batch)	踢 Tī (kick)	[i]
2	烏 Wū (grey)	孤 Gū (solitary)	呼 Hū (call)	哭 Kū (cry)	撲 Pū (bash)	[u]
3	迂 Yū (round)	居 Jū (live)	趨 Qū (trend)	須 Xū (must)	驢 Lǘ (donkey)	[y]
4	波 Bō (ball)	摸 Mō (touch)	潑 Po (splash)	窩 Wō (nest)	播 Bō (play)	[o]
5	鵝 É (goose)	哥 Gē (brother)	科 Kē (subject)	喝 Hē (drink)	各 Gè (each)	[7]
6	啊 A (ah)	巴 Ba (ba)	發 Fā (send)	哈 Hā (ha)	媽 Mā (mother)	[a]
7	資 Zī (capital)	詞 Cí (word)	斯 Sī (Adams)	死 Sǐ (die)	紫 Zǐ (purple)	[I\]
8	吃 Chī (eat)	師 Shī (teacher)	知 Zhī (know)	日 Rì (day)	支 Zhī (support)	[1]
9	的 De (of)	樂 Lè (music)	訥 Nè (ne)	德 Dé (virtue)	特 Tè (special)	[@]
10	誒 Éi (eh)	背 Bèi (back)	飛 Fēi (fly)	美 Měi (beauty)	陪 Péi (accompany)	[E]

No.	Traditional Chinese Characters with Monophthongs and Transcriptions in Cantonese (English meaning of words are in brackets)					SAMPA
1	碟 dip6 (dish)	喼 gip2 (gip)	疊 dip6 (stack)	摺 jip1 (fold)	葉 jip6 (leave)	[i]
2	血 hyut3 (blood)	雪 syut3 (snow)	缺 kyut3 (lack)	絕 zyut3 (absolute)	脫 tyut3 (off)	[y]
3	出 ceot1 (out)	術 seot6 (method)	恤 seot1 (shirt)	摔 seot1 (wrestle)	卒 zeot1 (soldier)	[e]
4	寫 se2 (write)	些 se1 (some)	嗲 de2 (whine)	爹 de1 (father)	借 ze3 (borrow)	[E]
5	乾 gong1 (dry)	湯 tong1 (soup)	裝 zong1 (contain)	康 hong1 (health)	幫 bong1 (help)	[O]
6	腳 goek3 (foot)	卻 koek3 (but)	雀 zoek3 (bird)	著 zoek5 (wear)	削 soek3 (cut)	[9]
7	入 jap6 (in)	甩 lat1 (throw)	凹 lap1 (concave)	凸 dat6 (convex)	漆 cat1 (paint)	[6]
8	八 baat3 (eight)	百 baak3 (hundred)	搭 daap3 (take)	鴨 aap3 (duck)	鴿 gaap3 (pigeon)	[a]
9	姑 gu1 (aunt)	烏 wu1 (grey)	估 gu3 (guess)	壺 wu5 (pot)	苦 fu2 (bitter)	[u]
10	福 fuk1 (bless)	屋 uk1 (house)	谷 guk1 (valley)	僕 puk1 (servant)	木 muk6 (wood)	[U]
11	色 sik1 (color)	漬 zik3 (dirt)	適 sik1 (fit)	食 sik6 (eat)	憶 jik1 (memory)	[I]