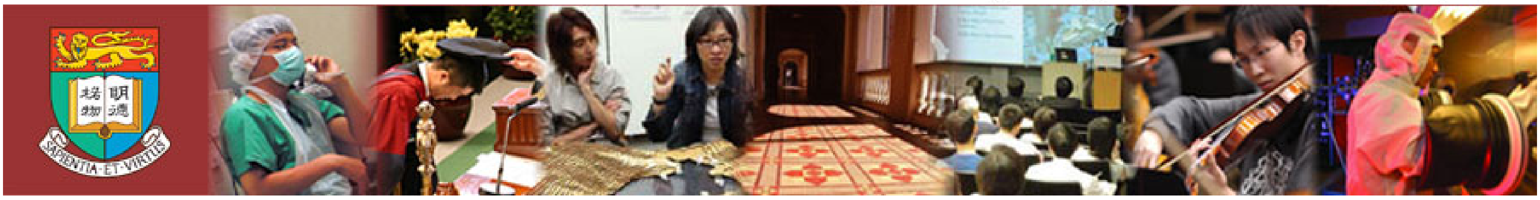

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**Vowels of Hong Kong English: from an acoustic perspective**

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## Abstract

The present study investigated how the vowel system of the first language (Cantonese) affects the acquisition of vowels of a second language. Forty native Cantonese-speaking adults (20 males and 20 females), with ages between 19 years 4 months and 26 years 10 months were recruited. Data from the first and second formant frequencies indicated that, for both female and male speakers, production of American English vowels was influenced by the Cantonese vowel system. This is also true even for those English vowels that were found in Cantonese. The perceptual ability in identifying the English vowels was also carried out to account for the deviated production of American English. It is found that perceptual and production abilities are related.

# Vowels of Hong Kong English: from an acoustic perspective

Cantonese is a dialect of Chinese. It is the first language spoken by the people residing mainly in the southern China including Hong Kong. In Hong Kong most of the native speakers of Cantonese speak English as their second language. Although most children in Hong Kong start to learn to speak English as early as in the kindergarten, English spoken by native Cantonese speaking Hong Kong people is usually judged to be heavily accented. Accent is defined as non-native like pronunciation (e.g. Markham, 1997; Major, 2001; Flege, Bohn, & Jang, 1997). Inaccurate production of English vowels is one of the major sources of accent (Markham, 1997).

## *Vowel Systems in Cantonese and English*

In English, there are 11 monophthongs /ɪ, i, e, æ, ɑ, ɔ, ʊ, u, ɛ, ʌ, o/ (Chen, Robb, Gilbert, & Lerman, 2001). They are classified by the place of articulation in terms of tongue height and anterior- posterior constriction position (Peter, 2001). Tense-lax vowels are considered as distinct vowels in English. Peter (2001) claimed that tense and lax vowels are similar in vowel quality, but ‘lax vowel is shorter, lower, and slightly more centralized than the corresponding tense vowel’ (p.81). In English, there are suggested three pairs of tense-lax vowels - /ɪ, i/, /e, æ/, and /ʊ, u/. However, in Cantonese, tense and lax vowel are not distinctive and only considered as allophones of each other (Bauer & Benedict, 1997). Bauer and Benedict (1997) carried out an in-depth study of Cantonese phonology. They concluded that Cantonese comprises of eight monophthongs - /i, y, ɛ, œ, a, ɐ, u, ɔ/ and 13 allophones /iː, ɪ, yː, ɛː, e, œː, ø, ɐ, aː, uː, ʊ, ɔː, o/. Similarly, Cantonese vowels are classified in terms of tongue height and front-back constriction position.

## *Acoustic Theory of Vowel Production*

### *The Source-Filter Theory*

Research on second language acquisition often uses phonetic symbols such as International Phonetic Alphabet (IPA), or the acoustic measurement of formant frequencies, to compare the phonetic inventories of first language (L1) and second language (L2). Though International Phonetic Alphabet (IPA) is commonly used worldwide as a phonetic symbol system to represent pronunciation, the same phonetic symbol may actually represent different configurations of the articulators in the production of different phonemes in different languages (Flege, 1987). For example, Flege (1987) claimed that although /u/ is present in both the phonetic inventories of French and English, the tongue position in producing the French /u/ is in a more posterior position of the oral cavity than that in producing English /u/. Therefore, it may not be valid to represent actual vocal tract configuration during vowel production. The same IPA symbol may indicate different articulatory configurations.

Acoustic measurements yield more valid and objective information. Proposed by researchers (e.g. Fant,1970; Stevens & House, 1961), the source-filter theory can be used to understand vowel production. According to Fant (1970), vowel is produced as a product of the energy source from the larynx and the effect of vocal tract resonators. The laryngeal source determines various aspects of a speech sound including the loudness, voice quality, and pitch. Pitch is closely correlated with fundamental frequency. Fundamental frequency refers to the rate at which the vocal folds vibrate when driven by an outward flow of air stream from the lungs. The source energy is modified by the filter, the configuration of the vocal tract. Resonance is thus resulted, and formants are created. Formants are the frequencies at which energy peaks are found, and they are labeled as F1, F2, F3, etc. following the order they appear in the frequency spectrum (Fant, 1970). Each vowel can be identified by its first three formant frequencies (Kent & Read, 2002). However, usually first and second formant frequencies alone are adequate for identifying most vowels in English (Kent & Read, 2002).

*Tube Models of Vowel Production*

Fant (1970) suggested that independence between the energy source and the resonator. Formant frequency is only affected by articulatory configuration. In producing vowels, the vocal tract can be viewed as a tube, or a combination of tubes for resonance, depending on the tongue position of the vowel (Johnson, 2003). For example, in producing schwa, the vocal tract is a tube of uniform cross-sectional area. In producing the English vowel /ɑ/, the vocal tract is regarded as two tubes, a back tube with smaller cross-sectional area, and a front tube with larger cross-sectional area. In producing /i/, the vocal tract can be viewed as two tubes with similar cross-sectional areas which are separated by a constriction. Regardless of the articulatory gesture, the formant frequency of tube(s) is inversely proportional to the length of the tube (Johnson, 2003). The shorter is the tube, the higher is the formant frequency. Children have shorter vocal tract than adults, and women have shorter vocal tract than men. Therefore, vowels produced by children should have higher formant frequencies than adults, and females may have higher formant frequencies than males (Fant, 1970). Besides the length, the ratio between the cross sectional area of the front tube and back tube also influences resonance frequency (Fant, 1970). Fant suggested that an increase of the cross-sectional area of the front cavity would lead to an increase of F1. Kent and Read (2002) summarized Fant's argument and stated that the two lowest formant frequencies relate to articulation of vowels. They stated that F1 of vowel is related to tongue height. The higher is the tongue position, the lower is the F1 value. Meanwhile, F2 is related to the anterior-posterior position of the tongue during vowel production. The more posterior is the tongue, the lower is the F2 value. Pickett (1999) claimed that F1 was also influenced by place constriction during articulation. While constriction in the front cavity increased F1, constriction at larynx reduced F1. The formant frequencies associated with a vowel therefore indicate the positioning of the tongue inside the vocal tract during the production of that vowel. The discrepancy in F1 of a vowel indicates the tongue height and place of constriction, while deviation in F2 of reflects the difference in anterior-posterior position in producing the vowel. Therefore, the variance of F1 and/or F2 between a vowel in L1 and L2 should indicate the errors in production.

*Accent Theory*

Major (2001) reviewed early researches about accent when speaking a second language. Using Contrastive Analysis (CA), the main reason of having an accent in L2 is argued to be the transfer of phonological system of the L1 to that of L2. When acquiring L2, people discover the similarity in the phonological system between L1 and L2. The learner substitutes a new phoneme of L2 by the similar phoneme in L1 (e.g., Lado, 1957 as cited in Major, 2001).

In a more recent study, Flege (1992) introduced Speech Learning Model (SLM) and the concept of ‘equivalence classification’. In SLM, phonemes in L2 are classified into three types: ‘identical’, ‘similar’, or ‘new’. Flege argued that when learning L2, a similar phoneme is poorly acquired, as the learner would substitute it with a phoneme in L1 system; while acquisition of ‘new’ phoneme will be native like eventually. This theory is supported by Flege’s earlier study in 1987. Flege studied the production of ‘new’ and ‘similar’ phonemes of French vowels by English speaking individuals (Flege, 1987). He found that the new phoneme /y/ produced by the English speakers were not significantly different from that by native French speakers, regardless of French speaking experience. However, for the similar phoneme /u/, none of the English speaking subject, despite the extensive experience of speaking the L2 (an average of 11.7 years), attained native like /u/ in French, though the more experienced subjects were able to produce /u/ more similarly to the native speaker than the less experienced subjects.

Later studies have also supported the SLM. Chen et al. (2001) examined the familiar and unfamiliar English vowels produced by Mandarin adult speakers. They defined familiar vowels of their Mandarin subjects, who spoke English as L2, as common vowels found in the phonological systems of both English and Mandarin. These vowels may be viewed as ‘same’ and ‘similar’ vowels as suggested by Fledge (1992). Those English vowels that do not exist in Mandarin were defined as unfamiliar vowels, and ‘new’ vowels according to Fledge (1992). In Chen et al.’s study, however, the formant frequencies of the vowels in these two language systems were not compared. They noticed significant differences in the first (F1) and second (F2) formant frequencies of the familiar English vowels produced by both male and female Mandarin speakers. However, significant differences were also found in the unfamiliar vowels. Chen et al.’s findings of unfamiliar vowels opposed the SLM. They argued that this may be due to inability in perceiving the difference in acoustic features, and inability in the control of articulators. Chen et al. suggested an absence of perceptual evaluation was one of the limitations of their study. Therefore, it was hard to conclude that if the difference in the vowel production found in Chen et al.’s study was due to the lack of perceptual acuity in differentiating different vowels in the two phonological systems of the speakers or purely speech motor control.

Flege, Bohn, and Jang (1997) observed a relationship between the perception and production ability of L2 learners. They studied the production and perception ability of English vowels by four groups of speakers – German, Spanish, Mandarin and Korean, and found that subjects who were able to perceive English vowels more accurately tended to perform better in production of the corresponding English vowels. They also found that the production of L2 (English) was influenced by the vowel inventory of the subject’s L1. As the subjects identify a particular English vowel as a vowel in L1 inventory (‘similar’ vowel), they produced less native like vowel than those who identified the vowel as a new phoneme (‘new’ vowel). This finding supports Flege’s notion of SLM (Flege, 1992).

It can be concluded that the acquisition of the phonological system of L2 is influenced by the phonological system of L1, and by an ability to distinguish vowel quality, such as F1 and F2, between the vowels in L1 and L2. The present study is to investigate the influence of L1 on acquisition of L2, and the effect of perceptual ability on acquisition of the vowel system of F2. Perhaps, some other factors, such as age of acquisition, also play an important role in acquiring L2 (Markham, 1997). However, it is not the purpose of the present study.

*Purpose of the Present Study*

Previous researches n L2 acquisition have focused on various languages such as French spoken by English speakers (Flege, 1987), English spoken by French, Spanish, Chinese, and German (Flege et al., 1997; Chen et al., 2001). Hung (2000) carried out a study of the phonological system of Hong Kong English. He found that the English tense and lax vowels produced by his Cantonese speaking subjects were not acoustically significantly different in terms of vowel durations, and F1 and F2 values. However, the English vowels produced by the Cantonese-speaking subjects were not compared with those produced by native English speakers, or with the vowels in Cantonese. A systematic acoustical analysis of the English vowels spoken by Hong Kong people is lacking. In order to account for the accent produced in Hong Kong English, the ability in perceiving English vowels should be evaluated. Furthermore, the vowel systems between Hong Kong English and Cantonese, and that between Hong Kong English and American English should be compared.

The present study attempted to determine: (1) how the F1 and F2 of English vowels spoken by native Cantonese speakers resided in Hong Kong (HKE) are different from those of native American English (AE) speakers; (2) how vowels in HKE (L2) is affected by the vowel system of Cantonese (L1); and (3) if there is relationship between perception and production of English vowels in learning English as an L2.

The hypotheses of the present study are (1) the production of ‘familiar’ vowels will be more deviated than the ‘unfamiliar’ vowels from the corresponding vowel of AE, and will be similar with a vowel in Cantonese; (2) the production of 'unfamiliar' vowels will be native like; (3) perception ability and production ability is correlated.

# Method

## *Participants*

Forty native Cantonese speakers (20 males and 20 females) participated in the present study. A 29-year-old male speaker of native American English from Los Angeles was also recruited. The Cantonese-speaking female subjects were between 19.5 and 23 years of age, with a mean of 21.7 years. The male subjects were between 19.3 and 26.8 years of age with a mean age of 21.5 years. All of them obtained a grade C or above in oral English in Hong Kong Advanced Level Examination (HKALE). All participants passed the hearing screening at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz at 20 dB in a sound-treated room.

## *Materials*

The speech materials included the 11 English vowels (/ɪ, i, e, æ, ɑ, ɔ, ʊ, u, ɛ, ʌ, o/) produced in an /hVd/ context; and eight Cantonese vowels (/i, y, ɛ, œ, a, ɐ, u, ɔ/) produced in either /kVn/ or /kVŋ/ context. Tables 1 and 2 show the IPA symbols and the English words and Cantonese words with meanings, respectively.

Table 1.

*Eleven American English vowels and the corresponding words used in the present study*

| Vowel | Word | Vowel | Word | Vowel | Word | Vowel | Word |
|---|---|---|---|---|---|---|---|
| i | heed | ɪ | hid | ɛ | head | æ | had |
| u | who'd | ʊ | hood | ɑ | hod | ɔ | hawed |
| e | hayed | ʌ | hud | o | hoed | | |

Table 2.

*Eight Cantonese vowels and the corresponding words used in the present study*

| Vowel | Word | Vowel | Word | Vowel | Word | Vowel | Word |
|---|---|---|---|---|---|---|---|
| i | 堅 /kin/ | ɛ | 驚 /kɛŋ/ | y | 捐 /kyn/ | æ | 薑 /kæŋ/ |
| a | 奸 /kan/ | ɐ | 根 /kɐn/ | u | 官 /kun/ | ɔ | 肝 /kɔn/ |

*Data Collection*

*Native American English (AE) speaker*

Native American English (AE) vowels were elicited from the American English (AE) speaker. To obtain the speech samples, the speaker was instructed to produce the 11 English words listed in Table 1 at a comfortable level. Similar to the study reported by Peterson and Barney (1952), the /hVd/ syllable was embedded in a carrier phrase of ‘Say ___ again’. All speech samples were recorded by using a high quality recorder (M-Audio Mircotrack Professional 2-channel Mobile Digital Recorder), via a high quality microphone (M-Audio Aries Professional Condenser Vocal Microphone) in a sound-treated room. The productions made by the AE speaker were later used in the perception task.

*Cantonese-Speaking Subjects*

The Cantonese-speaking participants completed three experimental tasks: (1) production of English vowels (HKE), (2) production of Cantonese vowels, and (3) identification of English vowels. The entire procedure was carried out in a sound-treated room. The procedure used to obtain the productions of English and Cantonese vowels by the Cantonese speakers was similar to the recording of native American English vowels stated previously.

*production of Hong Kong English (HKE) vowels*

The Cantonese-speaking subjects were instructed to produce the 11 English words listed in Table 1 in a carrier phrase of ‘Say ___ again’. Each phrase was produced by each subject thrice in a randomized order. Thirty-three English phrases were obtained from each subject. A practice session was provided to each subject before recording in order to allow the subject to get familiar with the chosen English words. The /hVd/ syllable produced by the AE speaker was separated from the carrier phrase and used as materials in the practice session for the Cantonese-speaking subjects. Two experimenters were present throughout the entire experiment. If the syllable was judged to have misproduced the words by the two experimenters, the subject was required to listen to the word produced by the AE speaker, and produce the phrase again. The subject was allowed to repeat the phrase four times at most for each syllable. A total of 33 English phrases were produced by each subject.

*production of Cantonese vowels*

All Cantonese-speaking subjects also produced the eight Cantonese vowels listed in Table 2. The /kVn/ or /kVŋ/ syllable was embedded in a carrier phrase of ‘我要讀___俾你聽’ (‘I want to read ____ to you’). Similar to the production of English vowels, each carrier phrase was spoken by each subject thrice in randomized order. For each subject, a total of 24 Cantonese phrases were produced.

*identification of American English (AE) vowels*

The phrases produced by the AE speaker were used in the identification task. Each of the 11 phrases was presented to the subject thrice in a randomized order at a comfortable loudness level via high quality headphones. Each subject was required to identify the vowel which they perceived by forced choice of the 11 English words in Table 1. The subject was allowed to listen to the phrase as many times as he/she desired in each trial in order to obtain the best answer.

*Data Analysis*

The English and Cantonese vowels produced by each subject were acoustically analyzed. In order to acoustically describe how the vowels were produced, formant frequencies were used. A signal analysis software, Praat, was used to obtain F1 and F2 values. To avoid initiation and termination effects, only the medial 80% of the vowel was used for analysis. The F1 and F2 values of the vowels were evaluated by using linear predictive coding (LPC) analysis. The built-in LPC algorithm was used to superimpose the spectral peaks on the spectrogram. The first two spectral peaks of each frame were then calculated. These values were averaged to represent the mean F1 and F2 values.

For the identification task, the percent correct identification of each vowel was calculated and the pattern of mis-identification was also noted.

*Statistical Analysis*

The mean F1 and F2 values obtained from the English vowels produced by male and female Cantonese subjects were compared against the normative data reported by Kent and Read (2002) and Chen et al. (2001) (see Tables A1 and A2 in Appendix A). One-way ANOVA was carried out to determine if there is statistically significant difference in F1 and F2 between the 11 HKE vowels. To compare each vowel pair, Tukey HSD test of multiple comparisons was carried out.

## Results

### *Reliability Measurements*

Five percent of the entire data corpus (114 out of 2,280 speech samples) was randomly selected from the English and Cantonese vowels produced by the 40 Cantonese-speaking subjects for inter-rater and intra-rater reliability measurements. The selected speech samples were analyzed a second time by the primary investigator and another investigator. The first and second measurements made by the first investigator were used to calculate intra-rater reliability, and the measurements made by the first and second investigators were used to calculate for inter-rater reliability.

For intra-rater reliability, the average absolute error of F1 and F2 obtained from the first and second measurements made by the first investigator were 9.81 Hz and 20.66 Hz, respectively. The Pearson product-moment correlation coefficients (*r*) for F1 and F2 values were 0.994 and 0.995 ($p < 0.01$) respectively.

For inter-rater reliability, the average absolute error of F1 and F2 obtained from the measurements made by the first and second investigators were 12.98 Hz and 25.13 Hz, respectively. The Pearson product-moment correlation coefficients (*r*) for F1 and F2 values were 0.990 and 0.994 ($p < 0.01$) respectively. Both the average absolute error and Pearson product-moment correlation coefficients show that measurements obtained by the first investigator were reliable and consistent.

*Acoustic Findings*

*Cantonese Vowels*

The F1 and F2 values associated with the eight Cantonese vowels (/i, y, ɛ, œ, a, ɐ, u, ɔ/) produced by female and male Cantonese speakers are shown in Tables 3.

*Comparison of Cantonese and American English (AE) Vowel Systems*

The vowel spaces corresponding to the corner vowels /ɑ, i, u/ produced by male and female Cantonese speakers are displayed in Figures 1 and 2 respectively. Vowel spaces were developed based on the F1 and F2 values associated with the vowels. As indicated in Figures 1 and 2, for both Cantonese and English, the F2 of the front vowel /i/ and central vowel /ɑ/ for both female and male Cantonese speakers was slightly higher than the corresponding vowels in AE, and the back vowels /u/ are lower than the corresponding vowels in AE.

*Hong Kong English (HKE) Vowels and American English (AE) Vowels*

The F1 and F2 values of the vowels produced by the Cantonese subjects were compared by using Tukey HSD test of multiple comparisons. The results indicated that the vowels /ɑ/ and

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Table 3.

*Mean, standard deviation and range (in Hz) of F1 and F2 values of eight Cantonese vowels*

| Vowel | F1 (Hz) | | | F2 (Hz) | | |
|---|---|---|---|---|---|---|
| | Mean | SD | Range | Mean | SD | Range |
| | Female | | | | | |
| a | 874.48 | 148.35 | 582.70 – 1343.4 | 1659.17 | 130.01 | 1409.70 – 1963.60 |
| ɐ | 767.89 | 88.46 | 567.93 – 1007.5 | 1679.97 | 99.55 | 1413.90 – 1895.00 |
| ɛ | 688.59 | 73.15 | 536.44 – 865.67 | 2284.76 | 176.89 | 1704.90 – 2848.60 |
| œ | 654.64 | 66.63 | 490.51 – 804.38 | 1601.01 | 128.63 | 1155.70 – 1859.30 |
| i | 379.71 | 54.54 | 276.75 – 473.71 | 2860.05 | 159.01 | 2514.50 – 3281.70 |
| ɔ | 643.20 | 81.85 | 330.12 – 822.55 | 1068.88 | 94.47 | 866.93 – 1270.30 |
| u | 435.94 | 31.46 | 378.63 – 504.39 | 885.03 | 116.05 | 606.75 – 1147.00 |
| y | 413.95 | 35.3 | 298.61 – 495.58 | 2002.32 | 143.09 | 1735.7 – 2949.2 |
| | Male | | | | | |
| a | 727.20 | 852.22 | 556.51 – 912.98 | 1426.71 | 107.16 | 1209.10 – 1626.80 |
| ɐ | 653.30 | 57.74 | 521.18- 794.22 | 1442.55 | 113.80 | 1091.00 – 1709.30 |
| ɛ | 559.17 | 58.70 | 427.47 – 662.83 | 2075.58 | 152.87 | 1795.90 – 2387.50 |
| œ | 554.07 | 49.93 | 463.72 – 652.02 | 1489.00 | 92.44 | 1294.20 – 1735.10 |
| i | 299.18 | 30.27 | 252.82 – 414.86 | 2386.20 | 146.32 | 2132.50 – 2694.20 |
| ɔ | 569.95 | 82.78 | 411.00 – 770.31 | 878.76 | 81.84 | 736.10 – 1093.60 |
| u | 365.13 | 42.45 | 277.56 – 490.41 | 804.66 | 107.17 | 498.06 – 1066.40 |
| y | 337.33 | 35.83 | 821.64 – 432.86 | 1895.55 | 120.99 | 1517.80 – 2106.20 |

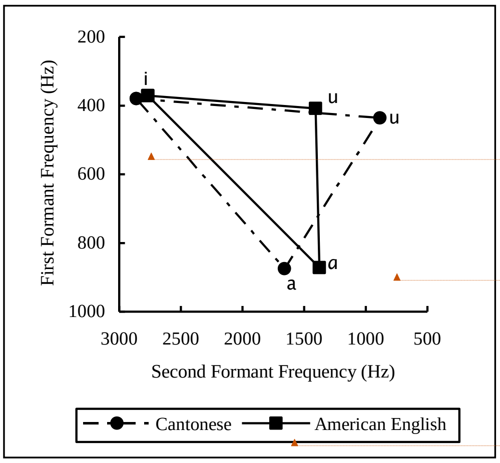


*Figure 1.* Plot of F1 against F2 of corner vowels of AE and Cantonese by female speakers

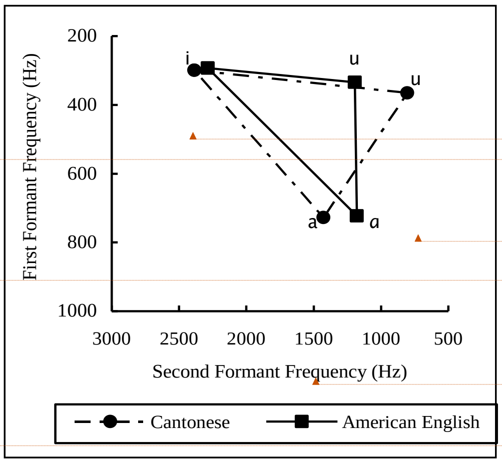


*Figure 2.* Plot of F1 against F2 of corner vowels of AE and Cantonese by male speakers

/ɔ/, and /e/ and /ɪ/ were not acoustically significantly different, in terms of their F1 and F2 values, for Cantonese-speaking females; while /ʊ/ and /u/ were not acoustically significantly different for Cantonese-speaking males.

The F1 and F2 frequency values of the 11 English vowels produced by female and male Cantonese speakers and the corresponding values of American English reported by previous researchers are shown in Tables 4. To compare HKE vowel system with AE vowel system, the vowel spaces associated with the HKE and AE vowels are depicted in Figures 3-6. Familiar vowels, those AE vowels that are also found in Cantonese, are shown in Figures 3 and 5 for female and male speakers respectively. The unfamiliar vowels are show in Figures 4 and 6 respectively.

The F1 and F2 of HKE and AE are displayed in Figures 7 and 8, for female and male speakers respectively. The Figures show how the F1 and F2 values of vowels between HKE and AE are differed. Generally, the F1 difference of vowels between HKE and AE is less than

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Table 4

*Mean, standard deviation, and range (in Hz) of F1 and F2 of 11Hong Kong English (HKE) vowels produced by Cantonese-speaking subjects, and mean (in Hz) of F1 and F2 of American English (AE)*.*

| Vowel | HKE | | | | | | AE* | |
|---|---|---|---|---|---|---|---|---|
| | F1 (Hz) | | | F2 (Hz) | | | F1 (Hz) | F2 (Hz) |
| | Mean | SD | Range | Mean | SD | Range | Mean | Mean |
| | | | | Female | | | | |
| i | 379.48 | 92.02 | 269.61 – 870.37 | 2765.59 | 207.54 | 5012.90 – 3067.90 | 371.44 | 2767.00 |
| ε | 738.81 | 738.81 | 557.91 – 911.54 | 2043.74 | 153.67 | 1758.90 – 2446.70 | 689.00 | 2140.22 |
| ʌ | 701.38 | 105.08 | 425.05 – 910.37 | 1546.30 | 138.09 | 1229.80 – 1799.00 | 757.63 | 1594.63 |
| ɑ | 671.00 | 1126.41 | 423.88 – 961.90 | 1120.75 | 165.52 | 804.40 – 1568.70 | 871.75 | 1376.00 |
| u | 411.43 | 34.20 | 354.31 – 514.12 | 1007.89 | 177.60 | 750.83 – 1508.80 | 408.00 | 1406.89 |
| ɔ | 628.00 | 134.96 | 376.32 – 955.21 | 1078.76 | 188.34 | 708.12 – 1460.80 | 790.33 | 1185.22 |
| æ | 795.20 | 109.94 | 628.23 – 1123.00 | 1952.99 | 195.19 | 1625.30 – 2919.90 | 864.78 | 2045.78 |
| ɪ | 436.23 | 71.79 | 285.70 – 624.05 | 2505.03 | 280.02 | 1957.40 – 2960.20 | 487.78 | 2301.11 |

Table 4 (continued).

| Vowel | HKE | | | | | | AE* | |
|---|---|---|---|---|---|---|---|---|
| | F1 (Hz) | | | F2 (Hz) | | | F1 (Hz) | F2 (Hz) |
| | Mean | SD | Range | Mean | SD | Range | Mean | Mean |
| | | | | Female | | | | |
| ʊ | 415.77 | 43.42 | 305.82 – 531.23 | 1125.21 | 192.58 | 861.01 – 1676.70 | 515.67 | 1464.44 |
| e | 468.93 | 65.87 | 369.20 – 672.05 | 2579.55 | 165.59 | 2224.30 – 3049.80 | 501.40 | 2516.60 |
| o | 452.30 | 46.54 | 364.63 – 576.22 | 998.98 | 141.01 | 731.21 – 1480.70 | 539.67 | 1284.67 |
| | | | | Male | | | | |
| i | 304.76 | 33.04 | 242.23 – 381.44 | 2366.71 | 178.31 | 2093.60 – 1914.10 | 293.22 | 2286.78 |
| ɛ | 581.74 | 91.52 | 412.40 – 802.77 | 1939.37 | 146.87 | 1733.20 – 2352.10 | 552.556 | 1777.11 |
| ʌ | 605.71 | 106.45 | 348.28 – 797.28 | 1325.30 | 130.61 | 994.53 – 1613.90 | 610.25 | 1312.75 |
| ɑ | 592.30 | 122.76 | 300.94 – 868.46 | 985.05 | 176.32 | 663.38 – 1428.60 | 722.50 | 1180.25 |
| u | 348.01 | 32.30 | 256.80 – 413.65 | 896.42 | 248.33 | 502.64 – 1861.40 | 334.44 | 1194.33 |

Table 4 (continued)

| Vowel | Hong Kong English | | | | | | American English* | |
|---|---|---|---|---|---|---|---|---|
| | F1 (Hz) | | | F2 (Hz) | | | F1 (Hz) | F2 (Hz) |
| | Mean | SD | Range | Mean | SD | Range | Mean | Mean |
| | | | | Male | | | | |
| ɔ | 585.28 | 121.43 | 368.93 – 821.31 | 929.50 | 190.23 | 580.82 – 1929.60 | 634.13 | 1038.67 |
| æ | 647.58 | 108.67 | 480.68 – 979.61 | 1815.77 | 155.16 | 1536.90 – 2255.70 | 671.22 | 1736.89 |
| ɪ | 343.05 | 43.04 | 255.39 – 445.41 | 2251.99 | 181.44 | 1922.00 – 2681.00 | 425.33 | 1914.33 |
| ʊ | 353.90 | 43.40 | 275.46 – 447.13 | 980.10 | 242.29 | 624.64 – 1703.00 | 456.00 | 1244.89 |
| e | 401.06 | 38.72 | 332.82 – 527.33 | 2237.55 | 119.72 | 2045.00 – 2531.60 | 447.80 | 2027.80 |
| o | 445.26 | 55.75 | 335.76 – 627.77 | 838.49 | 615.89 | 502.64 – 2914.1 | 474.67 | 1113.67 |

Note

* The corresponding mean F1 and F2 frequency values of female American speakers reported by 9 previous studies, including (a) Peterson and Barney (1952); (b) Hillenbrand, Getty, Clark, and Wheeler (1995); (c) Zahorian and Jagharghi (1993); (d) Hagiwara (1995); (e) Yang (1996); (f) Childers and Wu (1991); (g) Assman and Katz (2000); (h) Lee, Potamianos and Narayanan (1999) (as cited in Kent and Read, 2002, p.111); and (i) Chen et al. (2001).

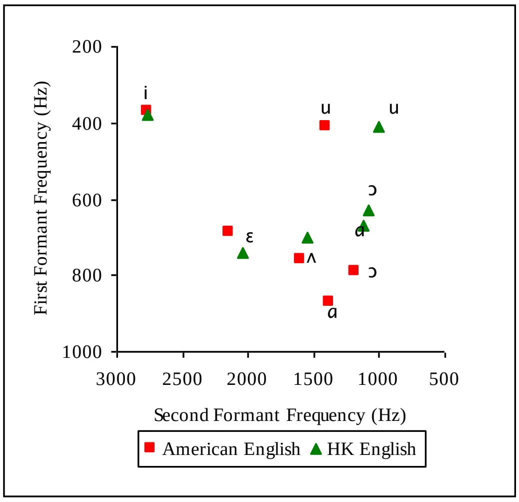


*Figure 3*. Plot of F1 against F2 of familiar vowels of AE and HKE by female speakers

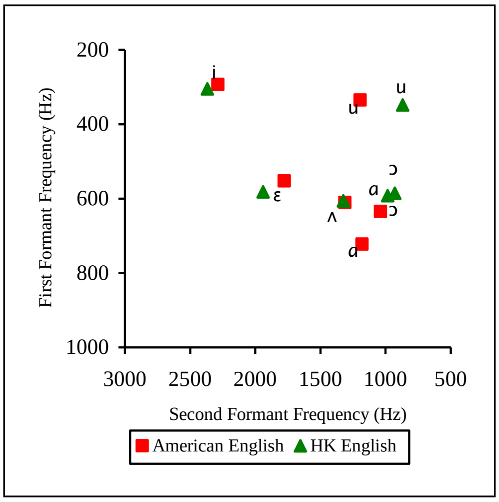


*Figure 4*. Plot of F1 against F2 of familiar vowels of AE and HKE by male speakers

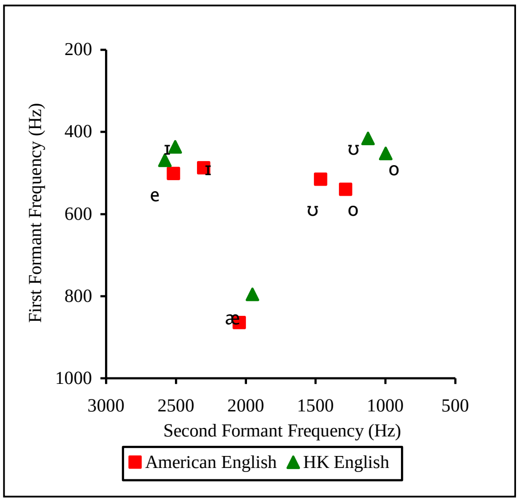


*Figure 5*. Plot of F1 against F2 of unfamiliar vowels of AE and HKE by female speakers

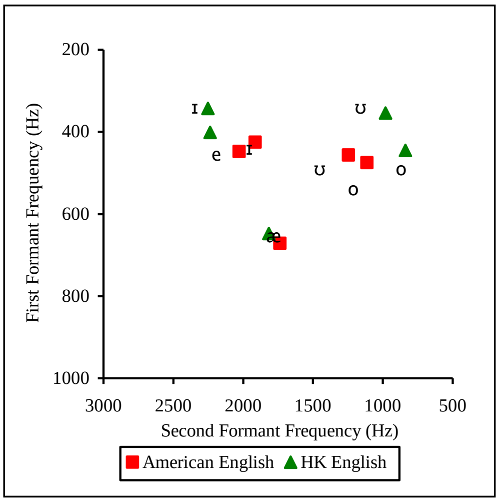


*Figure 6*. Plot of F1 against F2 of unfamiliar vowels of AE and HKE by male speakers

that of F2 difference.The only exception is the vowel /ɔ/ produced by female speakers, with F1 difference between HKE and AE is larger than F2 difference.

Chen (2006) used average Euclidean Distance (ED) between tense and lax vowels as a measurement to differentiate the vowel pairs. The ED is calculated based on the

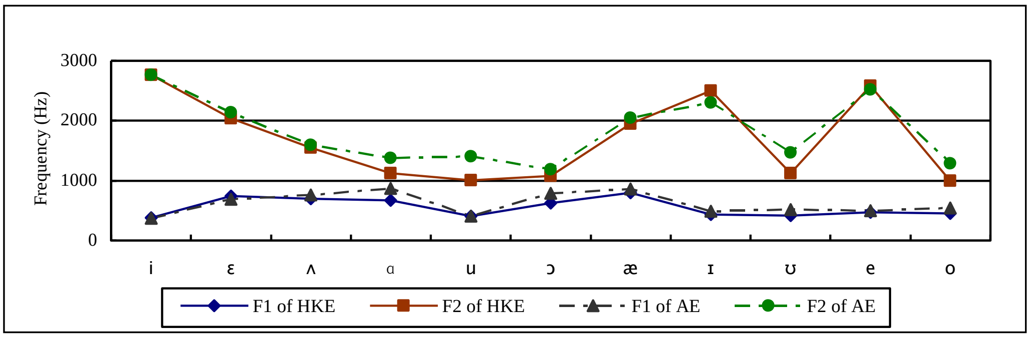


*Figure 7*. Comparison of F1 and F2 of HKE and AE vowels by female speakers

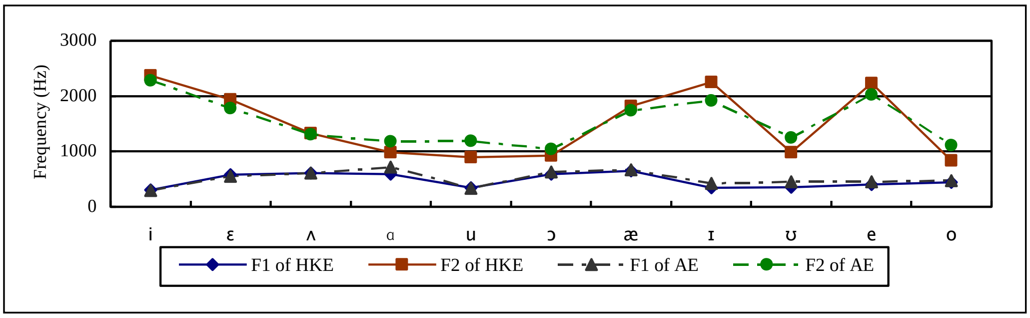


*Figure 8*. Comparison of F1 and F2 of HKE and AE vowels by male speakers

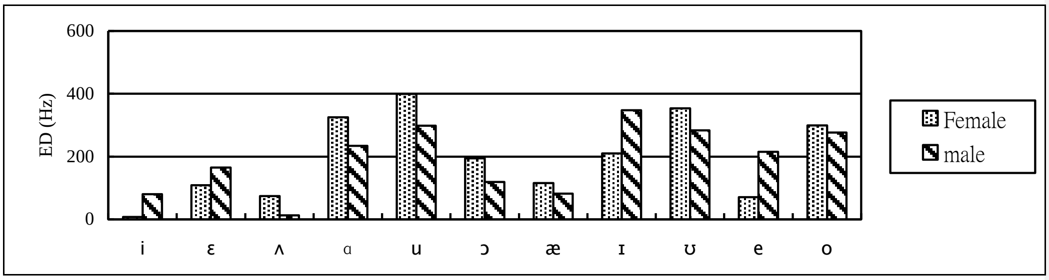


*Figure 9*. ED (in Hz) of English vowels between HKE and AE

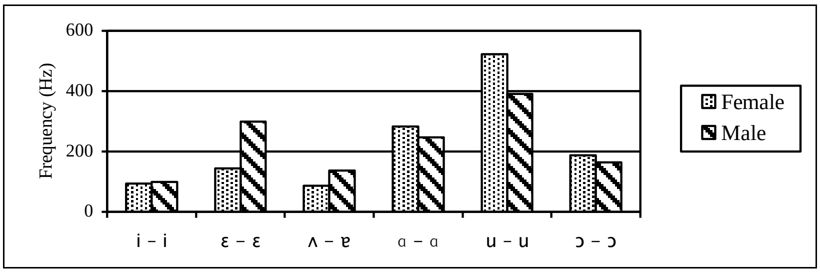


*Figure 10*. ED (in Hz) of familiar vowels between Cantonese and AE

Pythagorean Theorem and is used to measure the distance between two vowels in the same vowel space. For example, the F1 and F2 of the two vowels are ($F1_i$, $F2_i$) and ($F1_j$, $F2_j$) respectively, the equation of ED would be:

$$ED_{(i,j)} = \sqrt{(F1_i - F2_i)^2 + (F1_j - F2_j)^2}\ .$$

To determine the actual distance of a vowel between HKE and AE, ED of each English vowel of female and male speaker is calculated. The result is indicated in Figure 9.

*Perception of American English (AE) vowels by Cantonese-Speaking Subjects*

Table 5 shows the result that how the 11 AE vowels wereidentified by the female and male Cantonese-speaking subjects. As indicated in Table 5, the vowel /e/ was perfectly identified, whereas /ɑ/ and /u/ were poorly identified with below 50% accuracy by both male and female subjects. The vowel /ʊ/ (65% accuracy) was associated with the lowest percent correct identification by female subjects, and the vowel /ɔ/ was by male subjects (65% accuracy). The majority of Cantonese subjects tended to perceive vowels as tense vowels for the tense-lax vowel pairs - /ɪ, i/, /e, æ/, and /ʊ, u/.

Discussion

*Cantonese Vowel System vs. American English (AE) Vowel System*

As shown in Figures 1 and 2, the vowel spaces associated with the English vowels produced by Cantonese speakers, for both female and male, appear to be more extended when compared with that associated with American English vowels. This is true particularly in the F2 dimension. According to the source-filter theory suggested by Fant (1970), the F2 dimension is closely related to the tongue advancement during vowel production. It follows that tongue movement was more exaggerated in anterior-posterior dimension during English vowel productions by the Cantonese speakers when compared with the AE speakers. The high front vowel /i/ was produced with a more anteriorly placed tongue, while the high back

Table 5

*The % of times that the 11 AE vowels were identified by the Cantonese-speaking subjects*

| Target English vowels | Response by Female | Response by Male |
|---|---|---|
| i | i – 81.67% ɪ - 18.33% | i – 88.3% ɪ - 11.67% |
| ɛ | ɛ - 78.33% æ - 31.67% | ɛ - 91.67% æ – 8.33% |
| ʌ | ʌ - 86.67% ɛ, ɔ, o - 3.33%<br>æ, ʊ - 1.67% | ʌ - 76.67% o – 15%<br>ʊ, ɑ - 3.33% æ - 1.67% |
| ɑ | ɑ - 26.67% ɔ - 68.33%<br>ʌ - 3.33% o - 1.67% | ɑ - 35% ɔ - 58.33%<br>ʌ - 5% |
| u | u - 38.33% ʊ - 53.3%<br>o - 6.67% ʌ - 1.67% | u - 48.33% ʊ - 50%<br>o - 1.67% |
| ɔ | ɔ - 68.33% ɑ - 30%<br>ʌ - 1.67% | ɔ - 65% ɑ - 30%<br>ʌ - 3.33% æ -1.67% |
| æ | æ - 68.33% ɛ - 31.67% | æ – 71.67% ɛ - 28.33% |
| ɪ | ɪ- 95% i - 5% | ɪ- 95% i - 5% |
| ʊ | ʊ - 65% u - 30%<br>ɑ - 5% | ʊ - 76.67% u - 10% ʌ - 8.33%<br>o - 3.33% ɑ - 1.67% |
| e | e - 100% | e - 100% |
| o | o - 75% ɑ, u - 6.67% ʊ - 5%<br>ʌ - 3.33% ɔ - 1.67% | o – 73.33% ɑ - 10%<br>ʊ, u - 6.67% ɔ, ʌ - 1.67% |

vowel /u/ was produced at more posterior position by the Cantonese speakers. Deviation in F2 is also shown in another corner vowel /ɑ/, with Cantonese /ɑ/ has higher F2 than the AE /ɑ/. The tongue placement in producing /ɑ/ by Cantonese speaker is in more anterior position than AE speaker. These indicate that orthographic representation of phonemes was not a valid way of describing the vowel phonological systems of different languages. A vowel in one language may not be physiological and acoustically the same as the vowel in another of the same IPA symbol. IPA symbols do not seem to be able to describe the subtle differences between sounds of different languages.

The finding of the similarity of F1 and F2 between the Cantonese vowel /ɐ/ and American English /ʌ/ also supported this argument. When comparing the F1 and F2 of Cantonese /ɐ/ and AE /ʌ/ in Table 3 versus Table 4, it can be found that Cantonese /ɐ/ and AE /ʌ/ are acoustically similar, in terms of F1 and F2. Figure 10 indicates the ED of familiar vowels between Cantonese and AE. It indicated that the ED between Cantonese /ɐ/ and AE /ʌ/ is the smallest among the six familiar vowels for female speakers; while it is the second smallest for male speakers. Although the English vowel /ʌ/ does not orthographically match with any Cantonese vowel, the acoustic features, its location in the vowel space is similar to that of /ɐ/ in Cantonese.

*Hong Kong English (HKE) Vowel System vs. American English (AE) Vowel System*

Figures 7 and 8 show that the difference between F1 value of Hong Kong English (HKE) vowels and American English (AE) vowels was found to be smaller than that of F2 value for both female and male subjects, except for the vowel /ɔ/ produced by female subjects (see Figures 7 and 8). The stability of F1 values of vowels, both familiar and unfamiliar vowels, in HKE and AE suggested that HKE speaker has well acquired the tongue height and place of constriction in learning AE as L2. The source of accent production in vowels is due to the deviation in anterior-posterior tongue placement.

*Familiar Vowels /i, ɛ, ʌ, ɑ, ɔ, u/*

*vowel /ɑ/*

Comparing with data from AE, the corner vowel /ɑ/ produced by both female and male subjects attained longer ED (324.73 Hz and 234.64 Hz respectively) than most of the vowels (see Figure 9). The vowel /ɔ/ exhibited the least ED for both female and male subjects. This may be related to the production of the native AE speaker. All subjects were provided with a practice session to familiarize themselves with the target words. They were allowed to listen to the English vowels produced by the native AE speaker. The F1 of the vowel /ɑ/ produced by the native AE speaker was 682.07 Hz, while the F2 was 1057.60 Hz. Comparing these values with the normative data listed in Table 6, the vowel /ɑ/ produced by the native AE speaker was similar to the vowel /ɔ/ rather than /ɑ/ in the normative data. From the percent correct identification shown in Table 5, confusion between these two vowels existed. Both the male and female subjects misidentified a majority of /ɑ/ as /ɔ/ (over 50%). The subjects' production of the vowel /ɑ/ was suggested to be affected by the native AE speaker in the practice session. Therefore, /ɑ/ is excluded in the following discussion.

*Familiar Vowels /i, ɛ, ʌ, ɔ, u/*

Results from the present study suggest that, in acquiring L2, familiar vowels were substituted by the corresponding vowels in L1. When comparing Figures 9 and 10, the ED of between HKE and AE, and that between HKE and Cantonese appeared to be positively related. The larger is the ED of a vowel between AE and Cantonese, the larger is the ED between AE and HKE, except for the vowel /ʌ/ produced by male subjects. Furthermore, the

ED values between HKE and Cantonese are greater than that between HKE and AE. This finding supports the SLM which states that familiar vowels are substituted by the corresponding vowels in the phonological system of L1. However, the familiar vowels in English were not really identical to those in Cantonese which is indicated by the difference in F1 and F2 (see Tables 3 and 4). This may be due to the long time practice in HKE speakers. All subjects were regarded as experienced and fluent English speakers, who scored grade C or above in oral English of Hong Kong Advanced Level Examination (HKALE). Flege et al. (1997) found that experience was one of the factors in producing accurate vowels in L2. Flege et al.'s findings suggested that experienced speakers can better perceive and produce vowels in L2 than the inexperienced speakers in L2 of their German, Spanish, Mandarin, and Korean subjects.

*Unfamiliar Vowels /ɪ, æ, ʊ, o, e/*

The original hypothesis was that unfamiliar vowels produced by Cantonese-speaking subjects will be native like, as indicated by the shorter ED in unfamiliar vowels than familiar vowels between HKE and AE. However, the present result does not perfectly support the hypothesis. For the female subjects, although EDs of unfamiliar vowels are shorter than that of familiar vowel /u/, three out of the five unfamiliar vowels were associated with longer ED than the similar vowel /ɔ/. For the male subjects, four out of the five unfamiliar vowels were associated with longer ED (over 200 Hz). Only one of the unfamiliar vowels /æ/ has ED shorter than 100 Hz. This reflects that the unfamiliar vowels in English as L2 were generally acquired poorer than the familiar vowels by Cantonese-speaking individuals. The main source of accent due to vowel in HKE contributes to the unfamiliar vowels.

*lax vowels*

The findings contradictory to the SLM can be partly explained by the tense-lax features of the English vowel system and the perceptual ability of Cantonese- speaking subjects. Of the five unfamiliar vowels, three (/ɪ, æ, ʊ/) are the lax vowel counterparts of familiar vowels (/i, ɛ, u/, respectively). Peter (2001) suggested the similarity of vowel quality of the tense-lax English vowel pairs in Cantonese speakers. The tense and lax vowels are not distinctive in Cantonese; they are only considered as allophones of each others (Bauer & Benedict, 1997). The absence of the tense-lax contrast in Cantonese and the similarity of the vowel quality of the pair resulted in poor discrimination between the tense and lax vowels. As indicated in Tables 5, confusion of the tense-lax vowel pairs is present in both female and male subjects. Listeners perceived the target vowel only as the tense or lax counterpart for the pair /i – ɪ/ and /æ – ɛ/, and in majority for the pair /u – ʊ/.

When comparing the vowel spaces associated with AE, HKE and Cantonese in Figure 3 versus Figure 5 for female, and Figure 4 versus Figure 6 for male, it can be observed that both female and male subjects tended to articulate the lax vowels in a way similar to the tense vowel counterparts. For the female Cantonese subjects, the lax vowel /ɪ/ was produced with a slightly lower F1 and higher F2 than the /ɪ/ in AE, close to the tense counterpart /i/ which has tongue constriction in more anterior and upper part of the oral cavity. The tendency of tense vowel articulatory gesture in lax vowel production was more obvious for the pair /u – ʊ/. Both F1 and F2 values of /ʊ/ of HKE were different from those of AE, with lower F1 and F2 values in HKE than in AE (see Figures 7 and 8). This may implies that the /ʊ/ in HKE involved greater pharyngeal constriction and more posterior tongue retraction than that in AE. However, smaller ED was found for the lax vowel /æ/ than the other two lax vowels. Similar patterns were found in the productions by the male subjects.

Although perceptual confusion of tense-lax vowel pairs was in line with the deviated production of familiar vowels, the relationship between perception and production is not positively related. High accuracy of identification of particular vowel does not always imply short ED (i.e. greater similarity in F1 and F2). This may be related to the fact that tense and lax vowels are different not only in F1 and F2, but also in other dimensions, such as duration (Chen, 2006; &Peter, 2001). Peter (2001) observed that tense and lax vowels also differ in vowel duration, which may affect the vowel quality. Further investigation is required to clarify the relation.

*diphthongs - /e/ and /o/*

Among the new vowels, /e/ and /o/ can be regarded as diphthongs /eɪ/ and /oʊ/ respectively (Peter, 2001). In producing diphthongs, articulators move smoothly from the onglide to the offglide, resulting in a change of F1 and F2 over time. Figure 11 shows a wide-band spectrogram of the word ‘hoed’ /hod/ produced by a female subject. The darkened regions indicate regions of more intense energy, or the formant frequencies. The black spots in the spectrograms indicated the estimated formant frequencies across time. A slight decrement in F1 and increment in F2 can be noted. These reflect the tongue constriction moves forwards when articulating the vowel /o/, as /ɔ/ moves towards /ʊ/. Acoustically, the change in F1 and F2 apparently reflected the calculation of average F1 and F2 values. Caution should be taken when interpreting the data.

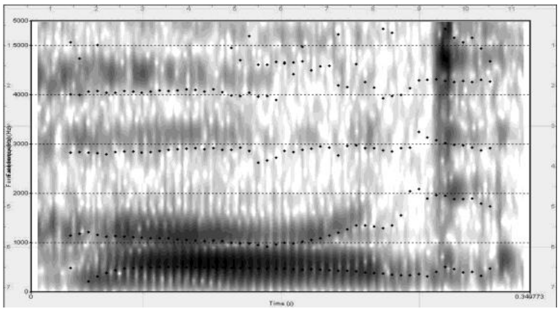

Figure 11. *Spectrogram of the vowel /o/ that was produced by one of the female subjects.*

If /e/ and /o/ are regarded as diphthongs, they become familiar diphthongs /ei/ and /ou/ in Cantonese. Further investigation should be carried out in comparing the acoustic features of AE /e/ and Cantonese /ei/, and that of AE /o/ and Cantonese /ou/.

## Conclusion

Results of familiar vowels from the present study support one of the arguments of SLM: Familiar vowels in L2 (English) appeared to be substituted by the corresponding phonemes in L1 (Cantonese). However, another argument of SLM that unfamiliar vowels are better acquired by L2 learners than familiar vowels is not confirmed. The perception ability of L2 learners is found to influence the production ability. This is evidenced by the confusion observed in identifying the tense-lax vowel pairs, the greater ED of the lax vowels, and similarity between the vowel spaces of tense and lax vowels in HKE.

Further investigation is required (1) to determine the relationship between the perceptual and production ability of tense-lax vowels in terms of formant values and vowel duration, and (2) to compare the acoustic features of the English vowels /e/ and /o/, with the Cantonese diphthongs /ei/ and /ou/, respectively.

## Clinical Application

As Cantonese speakers' identification and differentiation of tense and lax English vowels is found to affect their production of English vowels, English learning and accent reduction course perhaps should begin with perception exercise. Increased exposures to tense-lax vowel pairs are suggested to increase the identification ability of Cantonese speakers. Furthermore, caution should be especially taken in anterior-posterior tongue placement for producing native like American English vowels.

## Acknowledgment

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Appendix A

Table A1

*Mean F1 and F2 values of eleven American English monophthong vowels produced by native adult female speakers from study: (a) Peterson and Barney (1952); (b) Hillenbrand, Getty, Clark, and Wheeler (1995); (c) Zahorian and Jagharghi (1993); (d) Hagiwara (1995); (e) Yang (1996); (f) Childers and Wu (1991); (g) Assman and Katz (2000); (h) Lee, Potamianos and Narayanan (1999) (as cited in Kent and Read, 2002, p.112); and (i) Chen et a.l (2001).*

| Study | Vowel | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | i | ɪ | e | ɛ | æ | ɑ | ɔ | o | ʊ | u | ʌ |
| | F1 | | | | | | | | | | |
| (a) | 310 | 430 | --- | 610 | 860 | 850 | 590 | --- | 470 | 370 | 760 |
| (b) | 437 | 483 | 536 | 731 | 669 | 936 | 781 | 555 | 519 | 459 | 753 |
| (c) | 338 | 486 | --- | 745 | 922 | 981 | 793 | 532 | 528 | 400 | --- |
| (d) | 362 | 467 | 440 | 806 | 1017 | --- | 947 | 516 | 486 | 395 | 847 |
| (e) | 390 | 466 | 521 | 631 | 825 | 782 | 777 | 528 | 491 | 417 | 701 |
| (f) | 378 | 512 | --- | 661 | 842 | 838 | 745 | --- | 522 | 409 | 724 |
| (g) | 429 | 522 | 572 | 586 | 836 | 688 | 816 | 636 | 516 | 430 | 767 |
| (h) | 360 | 532 | --- | 694 | 787 | 894 | 726 | --- | 595 | 412 | 740 |
| (i) | 339 | 492 | 438 | 737 | 1025 | 1005 | 938 | 471 | 514 | 380 | 769 |
| | F2 | | | | | | | | | | |
| (a) | 2790 | 2480 | --- | 2330 | 2050 | 1220 | 920 | --- | 1160 | 950 | 1400 |
| (b) | 2761 | 2365 | 2530 | 2058 | 2349 | 1551 | 1136 | 1035 | 1225 | 1105 | 1426 |
| (c) | 2837 | 2284 | --- | 2123 | 2089 | 1440 | 1176 | 1419 | 1437 | 1617 | --- |
| (d) | 2897 | 2400 | 2655 | 2152 | 1810 | --- | 1390 | 1392 | 1665 | 1700 | 1735 |
| (e) | 2826 | 2373 | 2536 | 2244 | 2059 | 1287 | 1140 | 1206 | 1486 | 1511 | 1641 |

Table A1 (continued)

| Study | Vowel | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | i | ɪ | e | ɛ | æ | ɑ | ɔ | o | ʊ | u | ʌ |
| | F2 | | | | | | | | | | |
| (f) | 2586 | 2197 | --- | 2013 | 1933 | 1246 | 1190 | --- | 1386 | 1361 | 1445 |
| (g) | 2588 | 2161 | 2309 | 2144 | 2051 | 1273 | 1203 | 1470 | 1685 | 1755 | 1751 |
| (h) | 2757 | 2183 | --- | 2057 | 2078 | 1459 | 1079 | --- | 1522 | 1388 | 1609 |
| (i) | 2861 | 2267 | 2553 | 2141 | 1993 | 1532 | 1433 | 1186 | 1614 | 1275 | 1750 |

Table A2

*Mean F1 and F2 values of 11 American English monophthong vowels produced by native adult male from study: (a) Peterson and Barney (1952); (b) Hillenbrand, Getty, Clark, and Wheeler (1995); (c) Zahorian and Jagharghi (1993); (d) Hagiwara (1995); (e) Yang (1996); (f) Childers and Wu (1991); (g) Assman and Katz (2000); (h) Lee, Potamianos and Narayanan (1999) (as cited in Kent and Read, 2002, p.111); and (i) Chen et al. (2001).*

| Study | Vowel | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | i | ɪ | e | ɛ | æ | ɑ | ɔ | o | ʊ | u | ʌ |
| | | | | | | F1 | | | | | |
| (a) | 270 | 390 | --- | 530 | 660 | 730 | 570 | --- | 440 | 300 | 640 |
| (b) | 342 | 427 | 476 | 589 | 588 | 768 | 652 | 497 | 469 | 378 | 623 |
| (c) | 272 | 410 | --- | 550 | 656 | 749 | 637 | 456 | 439 | 324 | --- |
| (d) | 291 | 418 | 403 | 529 | 685 | --- | --- | 437 | 441 | 323 | 574 |
| (e) | 286 | 409 | 469 | 531 | 687 | 638 | 663 | 498 | 446 | 333 | 592 |
| (f) | 303 | 439 | --- | 542 | 645 | 673 | 615 | --- | 487 | 342 | 591 |
| (g) | 300 | 445 | 497 | 534 | 694 | 754 | 654 | 523 | 426 | 353 | 638 |
| (h) | 292 | 458 | --- | 590 | 669 | 723 | 601 | --- | 501 | 342 | 610 |
| (i) | 283 | 432 | 394 | 578 | 757 | 745 | 681 | 437 | 455 | 315 | 614 |
| | | | | | | F2 | | | | | |
| (a) | 2290 | 1990 | --- | 1840 | 1720 | 1090 | 840 | --- | 1020 | 870 | 1190 |
| (b) | 2322 | 2034 | 2089 | 1799 | 1952 | 1333 | 997 | 910 | 1122 | 997 | 1200 |
| (c) | 2209 | 1859 | --- | 1740 | 1748 | 1192 | 1004 | 1176 | 1234 | 1396 | --- |
| (d) | 2338 | 1808 | 2059 | 1670 | 1600 | --- | 1248 | 1188 | 1366 | 1417 | 1415 |
| (e) | 2317 | 2012 | 2082 | 1900 | 1743 | 1051 | 1026 | 1127 | 1331 | 1393 | 1331 |
| (f) | 2172 | 1837 | --- | 1690 | 1622 | 1098 | 990 | --- | 1168 | 1067 | 1194 |

Table A2 (continued)

| Study | Vowel | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | i | ɪ | e | ɛ | æ | ɑ | ɔ | o | ʊ | u | ʌ |
| | F2 | | | | | | | | | | |
| (g) | 2345 | 1974 | 1982 | 1855 | 1809 | 1214 | 1081 | 1182 | 1376 | 1373 | 1455 |
| (h) | 2266 | 1851 | --- | 1707 | 1725 | 1204 | 929 | --- | 1269 | 1181 | 1288 |
| (i) | 2322 | 1864 | 1927 | 1793 | 1713 | 1260 | 1233 | 1099 | 1318 | 1055 | 1429 |