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An Acoustic Phonetic Analysis of Mandarin English Vowel Spaces

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An Acoustic Phonetic Analysis of Mandarin English Vowel Spaces

by

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Abstract

The objective of this project is to investigate whether or not Mandarin speakers produce English vowels intelligibly. This research replicates the methodology used by Peterson and Barney (1952) and Hillenbrand et al (1995) in their studies of General American English and Midwest English. In this study, 20 Mandarin speakers of English (10 males and 10 females) are asked to read 11 words contain all 11 English phonetic vowels. The participants in the study are college-aged students studying at Saint Cloud State University. They are divided into 4 subgroups based on their genders Length of Residency (LOR) in the USA. The four subgroups are as follows:

1. Five males with LOR < 1 year
2. Five males with LOR > 1 year
3. Five females whose LOR < 1 year
4. Five females whose LOR >1 year

Their speech samples were recorded using the same laptop (Model: MacBook Air; System: OS X Yosemite; Version: 10.10.5). The acoustic phonetic software Praat (Boersma & Weenink, 2018) is used for data collecting and measuring. The data is annotated and collected manually. The acoustic correlates measured are: F0, F1, F2, F3, Duration, and Intensity.

F1 and F2 are mostly focused in this research because they are the most robust cues for assessing the intelligibility of vowels. These measurements are used to determine whether or not the vowels produced by the participants mask each other. Masking thresholds are based on Koffi (2017). The effect of masking on intelligibility is assessed using Catford's (1987) Relative Functional Load calculations. Acoustic vowel spaces are created to help visualize how the various vowels produced by Mandarin speakers of English compare with those produced by their GAE counterparts. The analysis shows that intelligibility is severely compromised in the following vowel pairs: [ɪ] vs. [e], [u] vs. [ʊ], and [ɛ] vs. [æ].

Other vowel pairs are challenging but our data indicates that these are the vowels that the 20 participants have hard time producing irrespective of their LOR in the USA. Finally Pedagogical implications and applications are drawn for teaching these vowels to Mandarin speakers of English.

Keywords: vowel intelligibility, acoustic correlates, Mandarin Chinese, masking analysis, acoustic distance, vowel space

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Chapter I: Introduction

Chapter Introduction

Peterson and Barney's (1952) study of the acoustic characteristics of English vowels is widely cited in many acoustic studies. The participants in Peterson and Barney's studies are referred to as speakers of General American English (GAE). Hillenbrand, Getty, Clark, and Weaver (1995) replicated their methodology to study the Midwest vowels. I also replicate the same classic methodology to study the vowels of English produced by 20 Mandarin speakers. The participants are further divided into different subgroups based on their gender and Length of Residency (LOR). In doing so, we wish to determine whether or not LOR has any beneficial effects on the intelligibility of vowels.

The goal of this study is to answer the following questions adapted from *The Acoustic Vowel Spaces of L2 English* (Koffi, 2017):

1. Can Mandarin speakers manage to produce English vowels intelligibly?
2. If they cannot, what vowel(s) do they use to substitute for it/them?
3. Do the compensatory strategies used interfere with segmental intelligibility?
4. What are the possible pedagogical applications and implications?

Literature Review

Two nationwide studies. In 1952, Peterson and Barney did a nationwide acoustic phonetic study of GAE: *Control Methods used in a Study of Vowels*. In this study, they recruited 76 participants from all over United States of America. The participants included 33 men, 28 women, and 15 children. In 1995, Hillenbrand et al. replicated Peterson and Barney's study, but this study focused only on Midwest vowels. This study had 139 participants: 45 men, 48 women, and 46 children. Moreover, 89% of the participants were from Michigan's lower peninsula. The participants of both studies were asked to pronounce the vowels found in the following words: <*heed, hid, hayed, head, had, hod, hawed, hoed, hood, who'd, hud*>. Peterson and Barney (1952) didn't include the vowel [e] and [o] because they considered them as diphthongs. However, these two vowels which occur in the words <hayed>, and <hoed> were added by Hillenbrand et al. (1995). In addition, both Peterson and Barney's and Hillenbrand et al.'s studies included [ɛ˞], but it is excluded in this study because, rather than a phoneme, [ɛ˞] is an allophone [ə] when it is followed by [ɹ].

Others have also replicated the same methodology to study vowels produced by non-native speakers of English. Samar (2014) did a comparative study of Egyptian English and GAE. Lindsay (2012) did a similar study which focuses on the English vowels produced by Spanish speakers. Much like these studies, the current study follows the same methodology in answering the four research questions stated earlier.

Two vowel systems. GAE and Mandarin have different vowel systems. They differ from each other in both vowel number and vowel features.

General American English is considered to have an inventory of 11 vowels, as shown in the vowel quadrant below:

Table 1.1

General American English Vowel Quadrant

	front	central	back
high	/i/ <see> /ɪ/ <sit>		/u/ <sue> /ʊ/ <soot>
mid	/e/ <say> /ɛ/ <set>		/o/ <soak> /ɔ/ <salt>
low	/æ/ <sat>	/ʌ/ <such>	/ɑ/ <sod>

Note: This table is retrieved from the *Relevant Acoustic Phonetics of L2 English: Focus on Intelligibility* (Koffi, 2017, p. 12)

According to Abercrombie (1967), vowels can be classified geometrically in the horizontal axis and vertical axis. The vertical axis indicates the degrees that the mouth opens during articulation. This axis is related to the vowel height: that is, the higher the vowels are, the less widely the mouth opens. Conversely, the lower the vowels are, the more widely the mouth opens. In terms of the GAE vowels, /i, u, ɪ, ʊ/ are classified as high vowels. When producing these vowels, the mouth is barely open. /e, o, ɛ, ɔ/ are classified as mid vowels; the mouth opens slightly more widely than the high vowels while producing these vowels. The vowels /ʌ, æ, ɑ/ are classified as low vowels. The mouth opens more widely while producing these vowels than when producing the other vowels.

On the other hand, the horizontal axis indicates the tongue movement, and it is also related to the vowel backness. On this axis, all vowels can be classified as the front, central and back vowels. /i, ɪ, e, ɛ, æ/ are the front vowels, and the tongue moves to the front of the mouth while producing these vowels. /ʌ/ is classified as the central vowel. When producing /ʌ/, the tongue is at the center position of the mouth. The vowels /u, ʊ, o, ɔ, ɑ/ are classified as the back vowels; the position of the tongue is back toward the throat when producing these vowels.

When considering Mandarin vowels, however, there is a controversy over the number of vowels in Mandarin Chinese. Some linguists list six main vowels, while others list five vowels.

Odinye (2015) lists six vowels in Mandarin, which are: /a, e, o, i, u, ü/. These six vowels are the vowels this writer was taught in her first grade Chinese class. The vowels /i/ and / ü/ are classified as high fronted vowels. The vowel /u/ is a high back vowel. /o/ is a mid-back vowel. /a/ is only described as a low vowel; the degree of backness is not clarified in this study. Moreover, the vowel /e/ is classified as a central vowel, but the degree of height is not clarified. For the purposes of this study, the Mandarin vowels are presented as follows:

Table 1.2

Mandarin Vowel Quadrant Based on Odinye (2015)

	front	central	Back
high	/i/<yi> ü< nü>		u <hu>
mid		e (he)	o <wo>
low		a<ya>	

Lin (2001) contends that there are six phonemic vowels in Mandarin. Lin also agrees that /i/ and /ü/ are high front vowels; [i] is similar to the English vowel [i]. The vowel [ü] has no equivalent in English. /ɚ/ is considered as a mid vowel in this study, and it is often substituted for the English schwa by Mandarin speakers. The vowel /a/ is considered fairly similar to the English vowel /a/ in terms of the vowel height. However, /a/ in Mandarin is a central vowel, while /a/ in English is a back vowel. The sound /o/ is similar to the English vowel /o/. The back vowel /u/ is similar to the /u/ of English. Based on the vowel feature information from Lin's study, the Mandarin vowels can be arranged in the vowel quadrant below:

Table 1.3

Mandarin Vowel Quadrant Based on Lin (2001)

	front	central	back
high	/i/ <yi> ü/ <yü>		/u/ <nu>
mid			/ɚ/ <er> /o/ <wo>
low		a <ya>	

Duanmu (2005) excludes the /o/ and /ɚ/. He believes that there are five vowels in Mandarin: /i, y, u, ɤ, a/. Much like the other studies, /i, y, u/ are classified as high vowels. The vowel /i/ is a high unrounded vowel, which is similar to /i/ in GAE, while [y] is a front rounded vowel. This vowel has no equivalent vowel in GAE. The segment /u/ is a back rounded vowel, and it is acoustically similar to the vowel /u/ in GAE. /a/ is classified as a low central vowel. Duanmu (2005) has the vowel /ɤ/, which is not mentioned by the two other researchers cited in this study. He classifies /ɤ/ as a mid central vowel in regard to backness, and a mid vowel in regard to vowel height. Duanmu's vowels can be placed on the following quadrant:

Table 1.4

Mandarin Vowel Quadrant Based on Duanmu (2005)

	front	central	Back
high	/i/<yi> y< nü>		u <nu>
mid		ɤ <le>	
low		a<ya>	

According to the information above, some vowels are similar between Mandarin and GAE, and some are different.

Masking and intelligibility. Masking occurs when the F1 distance between two adjacent vowels that are phonetically similar but functionally different is less than 60 Hz (Koffi, 2017). Meanwhile, the acoustic threshold of 60 Hz is a robust acoustic criterion for distinguishing between perceptually similar vowels. If two vowels have an F1 distance greater than 60 Hz, we conclude that these two vowels do not mask each other. However, if the F1 distance between two vowels is less than 60 Hz, masking is likely.

Masking occurs if the F1 distance between two vowels is less than 60 Hz. Additionally, the masking levels are different because of the F1 distance range. Koffi (2018) has proposed a method based on the Critical Band Theory to correlate the F1 acoustic distances between adjacent phonemes and intelligibility. It is calculated on the basis of F1 frequency masking levels, as shown in Table 1.7 and explained thereafter.

Table 1.5

F1 Acoustic Distance and Masking/ Intelligibility Degrees

N0	F1 Distance	Masking Levels	Intelligibility Rating
1.	> 60 Hz	No masking	Good intelligibility
2.	41 Hz – 60 Hz	Slight masking	Above Average intelligibility
3.	21 Hz – 40 Hz	Moderate masking	Questionable intelligibility
4.	0 Hz – 20 Hz	Complete masking	Poor intelligibility

Note: Provided by Koffi (2018).

Table 1.8 provides the information about the F1 acoustic distance and masking/intelligibility degrees. If the F1 distance between two phonemic vowels is >60 Hz, these two vowels do not mask each other, and intelligibility is good. Masking is likely to occur when the F1 distance between two adjacent phonemic vowels is ≤ 60 Hz. The F1 distance of 41 Hz ~ 60 Hz causes slight masking/ above average intelligibility. When the F1 distance between vowels is between 21 and 40 Hz, the two vowels can be concluded as having moderate masking/ questionable intelligibility. Poor intelligibility occurs if the F1 distance between two vowels is ≤20 Hz. Because human beings cannot detect frequencies below 20 Hz (Ladefoged, 1996), no distinction can be made if the F1 distance between two vowels is ≤20 Hz.

Methodology

Participants. Twenty Chinese international students including ten males and ten females were recruited as the participants for this study. All of them were from the same exchange program and were attending St. Cloud State University at the time of collecting their data. The collection of the data was approved by the Institutional Review Board (IRB).

The 20 participants were further divided into four subgroups based on their genders and LOR. They were divided based on gender because there are gender differences in vocal tract ratio. They were further divided based on LOR in order to investigate if the LOR affects vowel intelligibility issues. The critical time frame used to determine LOR is ± 1 year, as shown in Tables 1.6 and Table 1.7. The suffix M refers to male and F refers to female.

Table 1.6

Male Participants Background Information

Participants	Length of Residency (LOR)
Participant 1M	LOR<1
Participant 2M	LOR<1
Participant 3M	LOR<1
Participant 4M	LOR<1
Participant 5M	LOR<1
Participant 6M	LOR>1
Participant 7M	LOR>1
Participant 8M	LOR>1
Participant 9M	LOR>1
Participant 10M	LOR>1

Table 1.7

Female Participants' Background Information

Participants	Length of Residency (LOR)
Participant 1F	LOR<1
Participant 2F	LOR<1
Participant 3F	LOR<1
Participant 4F	LOR<1
Participant 5F	LOR<1
Participant 6F	LOR>1
Participant 7F	LOR>1
Participant 8F	LOR>1
Participant 9F	LOR>1
Participant 10F	LOR>1

The LOR is indicated by <1 for those who have been in the U.S. for less than 1 year and >1 for those who have been in the U.S. for more than 1 year.

Material and data collection. The participants were asked to record themselves reading the words in Table 1.8.

Table 1.8

11 Words and Vowels

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

The recordings for this study used the Praat, version 6.0.43, a free software that was downloaded to the researcher's laptop (Model: MacBook Air; System: OS X Yosemite; Version: 10.10.5). In order to control the influence of the environment, the recordings were done in the same type of quiet study rooms located in the library of St. Cloud State University. Each participant was asked to record him/herself producing each word from the word list above three times in front of the laptop. The corpus that serves as the basis for this study consists of 660 vowel tokens (20x11x3).

Analysis

The collected data was further investigated by measuring the following acoustic correlates: F0, F1, F2, F3, intensity, and duration. All in all, 3,960 correlates were analyzed (660 x 6). However, only F1 and F2 values are used in this study to assess intelligibility because they are deemed the most relevant acoustic correlates for the study of vowels (Ladefoged & Maddieson, 1996, p. 282-292). F1 is related to the vowel height, and F2 is associated with the backness of vowels. In addition, for the first two formants, F1 correlates more strongly with intelligibility than F2 because it alone has 80% of the acoustic energy found in vowels (Ladefoged & Johnson, 2015).

Figure 1.1 is a sample spectrograph showing how the acoustic correlates are measured, including the onset and offset areas of vowels:

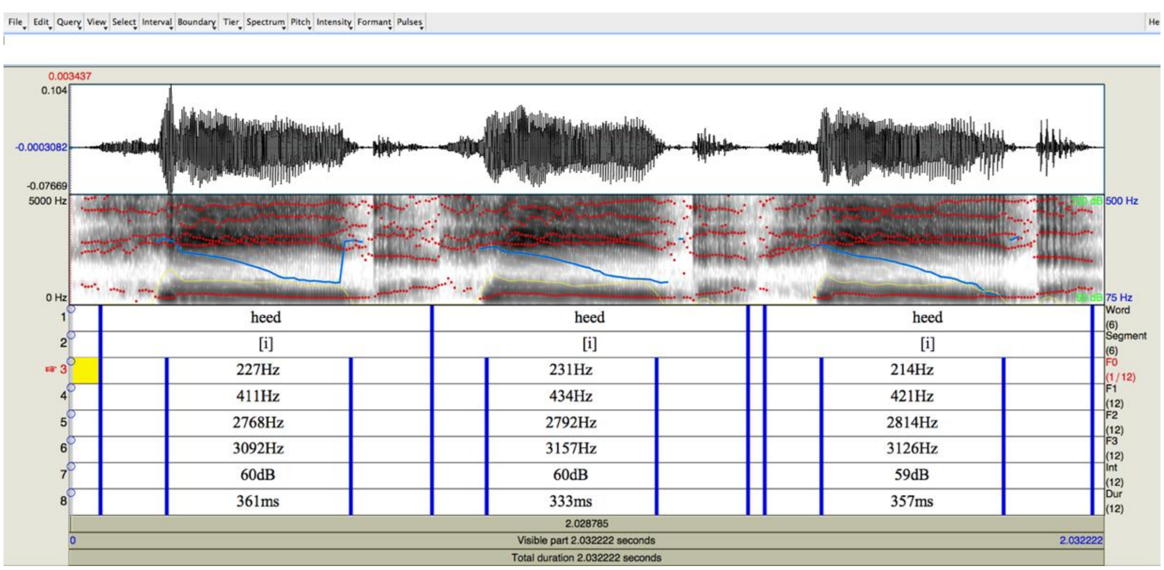

Figure **1.1** A Sample Spectrogram of <heed>

The numerical value of each correlate is tabulated and averaged for each speaker and across all 20 participants. The data of the speakers who belong to the same subgroup is further averaged and analyzed separately.

The first and second formants of each subgroup's vowels and those of GAE are plotted together in the same acoustic vowel space. The acoustic vowel space pictures how the speakers produce the vowels. Figure 1.2 is a sample acoustic vowel space of this researcher's English vowels and GAE vowels.

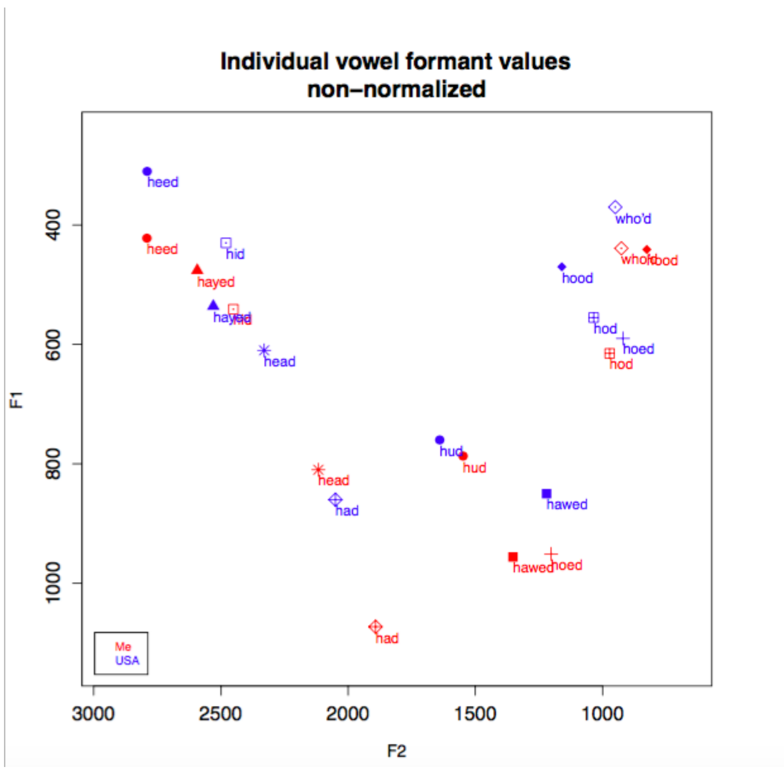

Figure **1. 2** A Sample Acoustic Vowel Space

According to Ladefoged, "Vowel charts provide an excellent way of comparing different dialects of a language" (Ladefoged, 2001, p. 43). He also states that the distance between any two sounds from the acoustic vowel space reflects how far apart they sound. Therefore, Figure 1.2 simulates how a listener perceives the vowels acoustically.

Conclusion

The analysis includes the following aspects: firstly, the F1 data of participants is presented in order to investigate how the Mandarin speakers produce the vowels similarly/differently to GAE in vowel height mouth aperture. F2 data of participants is then presented to find out how similar/different the Mandarin speakers' tongue position is when producing the vowels. The third part of the analyses is masking and intelligibility. It basically includes two parts: internal masking and intelligibility analysis, and external masking and intelligibility analysis. The former refers to how the Mandarin speakers' two adjacent vowels mask each other and how they result in intelligibility. External masking refers to how a vowel produced by Mandarin speakers masks its adjacent vowel produced by GAE speakers.

The analyses of male Mandarin speakers are presented first, and the same analyses of female Mandarin speakers are presented afterwards. Analyses of the two male subgroups LOR<1 and LOR>1 are shown first, followed by the two female subgroups LOR<1 and LOR>1.

Pedagogical implications and applications are provided based on the acoustic vowel space of all Mandarin speakers. In this section, problematic vowels are pointed out so that they can be focused on Mandarin English classes.

Chapter II. Masking and Intelligibility Assessment of Male Mandarin Speakers

Chapter Introduction

In this chapter, the English vowels produced by male Mandarin speakers are compared and contrasted with GAE vowels. The F1 and F2 values of both groups are plotted together in the acoustic vowel spaces. The F1 and F2 values of GAE males are taken from Peterson and Barney (1952, p.183). Masking degree and intelligibility rating of the vowels are assessed by using the masking/intelligibility threshold that was detailed in the previous chapter.

The current chapter includes four sections. The first part is related to the analysis of English vowels produced by ten male participants. The F1 and F2 values and the acoustic vowel space of the ten male participants are presented first. Then, the vowels masking degree and intelligibility rating are assessed. The second and the third sections perform the same analyses, but focus on the two subgroups: the participants with LOR<1 and those with LOR>1. The last section makes correlations between LOR and vowel intelligibility.

Masking and Intelligibility Assessment of Male Participants

F1 information of ten males. F1 is one of the most important parameters for describing vowels. It reflects the mouth aperture while producing a vowel. The higher the F1 value, the more widely the mouth opening. Conversely, the lower the F1 value, the less widely the mouth opening. As mentioned in Chapter One, Section 1.5, the acoustic threshold of 60 Hz is used as a robust acoustic criterion for assessing masking and intelligibility levels. Table 2.1 provides the F1 information of the ten male participants and that of the male GAE speakers.

Table 2.1

F1 Values of Ten Male Mandarin Speakers and Male GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
male1<1	314	347	345	688	749	333	580	419	324	321	777
male2<1	334	384	379	670	640	373	629	597	458	384	790
male3<1	295	309	306	613	596	571	522	288	298	291	757
male4<1	630	726	423	761	729	550	805	473	326	337	819
male5 <1	478	494	750	733	756	715	752	575	470	454	952
male6>1	308	295	408	717	784	713	779	501	439	310	814
male7>1	307	342	393	735	757	422	605	416	321	348	770
male8>1	285	520	452	927	907	859	681	627	415	352	845
male9>1	336	375	312	671	699	805	696	569	359	334	374
male10>1	328	335	387	720	692	454	693	490	412	391	781
St. Deviation	109	133	126	83	80	186	91	103	64	47	149
Participants' mean	362	413	416	724	730	580	674	496	382	352	768
GAE mean	270	390	476	530	660	730	570	497	440	300	640
Difference	92	23	60	194	70	150	104	1	58	52	128

When similar vowels are compared and contrasted with each other, the acoustic distance between them should be less than 60 Hz for optimal intelligibility. However, in the table above, some vowels have a distance greater than 60 Hz. For example, the distance between [i] in Mandarin-accented English (362 Hz) and GAE (270 Hz) is 92 Hz. Since Mandarin-accented [i] has a greater F1 frequency than GAE, it means that Mandarin speakers open their mouths more widely than GAE speakers. This also happens when Mandarin speakers produce the vowels [ɛ], [æ], [ɔ], [ʌ]. The F1 values of these vowels produced by the male Mandarin speakers have a distance of more than 60 Hz compared to GAE. This shows that when male Mandarin speakers produce these vowels, their mouths open more widely than GAE speakers.

The vowel [ɑ] of male Mandarin speakers and that of GAE also has an F1 distance of more than 60 Hz. However, the Mandarin-accented [ɑ] (580 Hz) is 150 Hz smaller than that of

GAE (730Hz), meaning that when male Mandarin speakers produce the vowel [ɑ], their mouths open less widely than GAE speakers.

Some Male Mandarin-accented vowels and male GAE vowels have an F1 distance equal to or less than 60Hz. These vowels include: [ɪ], [e], [o], [ʊ], and [u]. Since the acoustic distance of ≤ 60 Hz causes optimal intelligibility, it can be inferred that the intelligibility of these vowels is optimal. In the case of the vowel [o], the F1 distance between the Mandarin-accented [o] (496 Hz) and GAE's [o] (497 Hz) is a mere 1 Hz. This indicates that male Mandarin speakers produce the vowel [o] almost the same as male GAE speakers in terms of vowel height.

F2 information of ten males. F2 is the other relevant parameter in analyzing vowels. F2 provides information on the tongue position while a vowel is being produced. Front vowels always have higher F2 values, and back vowels always have lower F2 values. A difference in F2 values of 200 Hz is another threshold used for vowel analysis (Koffi, 2017, p.101). Table 2.2 provides the F2 information for vowels of ten male Mandarin speakers and male GAE speakers.

Table 2.2

F2 Values of Ten Male Mandarin Speakers and Male GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
male1<1	2219	2141	2073	1742	1639	1467	949	1033	2068	1831	1282
male2<1	2207	2109	2151	1644	1527	805	972	940	833	764	1197
male3<1	2461	2327	2302	1841	1824	1212	952	1228	1398	840	1264
male4<1	1794	1661	2171	1656	1755	1364	1185	1476	1079	943	1089
male5 <1	2123	2163	1768	1784	1768	1243	1176	1178	1096	1051	1413
male6>1	2284	305	2237	1963	1839	1081	1296	1067	1426	1099	1414
male7>1	2136	2044	2024	1687	1658	900	940	919	883	1013	1377
male8>1	2419	2151	2329	1703	1720	1296	1016	1840	1271	1066	1333
male9>1	2535	2383	2399	2016	1895	1501	1262	1336	1281	945	1107
male10>1	2152	2116	2012	1665	1675	915	1013	1384	1239	1081	1218
St. Deviation	211	606	186	131	109	244	139	282	347	291	117
Participants' mean	2233	1940	2147	1770	1730	1178	1076	1240	1257	1063	1269
GAE mean	2290	1990	2089	1840	1720	1090	840	910	1020	870	1190
Difference	57	50	58	70	10	88	236	330	237	193	79

If the F2 distance between two corresponding vowels is equal to or less than 200 Hz, it means that they are produced similarly. An F2 distance greater than 200 Hz shows that the two vowels are produced differently. On the basis of the information in Table 2.2, vowels produced by the male participants have an F2 distance less than 200 Hz, except for the vowels [ɔ], [o] and [ʊ].

The F2 distance between the male Mandarin speakers' [ɔ] (1076 Hz) and male GAE's [ɔ] (840 Hz) is 236 Hz. Mandarin male speakers' [o] (1240 Hz) and male GAE speakers' [ɔ] (910 Hz) have a distance of 330 Hz. The F2 distance between the [ʊ] of male Mandarin speakers (1257 Hz) and [ʊ] of male GAE speakers (1020 Hz) is 237 Hz. The Mandarin speakers' F2 of these three vowels are all greater than the GAE F2 of these vowels. This means that when Mandarin speakers pronounce words containing these vowels, their tongues are more forward than those of GAE speakers.

Acoustic vowel space of ten males. Figure 2.1 provides a visualization of the acoustic vowel space of vowels produced by both the ten male Mandarin speakers and male GAE speakers and how they relate to each other.

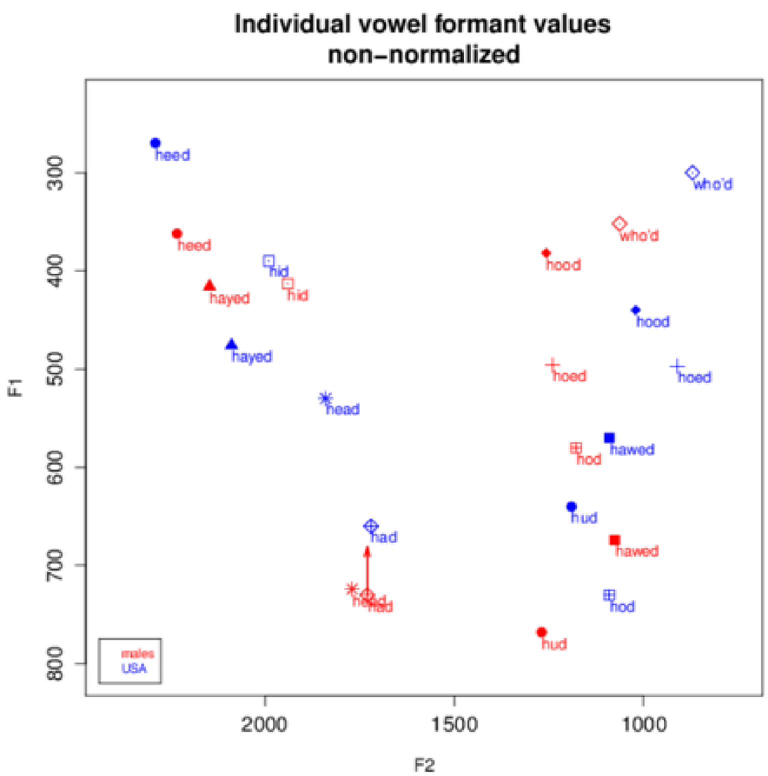

Figure **2.1** Acoustic Vowel Space of Ten Male Participants and Male GAE Speakers

Masking analysis is based on the acoustic vowel space. It includes two aspects: internal masking analysis and external masking analysis. Internal masking refers to how adjacent vowels produced by the same speaker mask each other, affecting intelligibility. On the other hand, external masking compares a participants' F1 of one vowel to a GAE speaker's F1 of an adjacent vowel. External masking data provides information of how a GAE hearer perceives a vowel when a speaker pronounces it. Both internal and external masking analyses use the acoustic distance and masking thresholds from Chapter One, Table 1.5.

Internal masking analysis of ten males. The vowels [i] (362 Hz) and [ɪ] (413 Hz) produced by the male Mandarin speakers, with an F1 distance of 51 Hz mask each other slightly. In other words, when male Mandarin speakers produce the words <heed> and <hid>, the intelligibility level is above average. However, the unintelligibility factor cannot be eliminated because the acoustic distance is below 60 Hz.

Complete masking occurs between the front vowels [ɪ] (413 Hz) and [e] (416 Hz), and also between [ɛ] (724 Hz) and [æ] (730 Hz). The F1 distance between [ɪ] and [e] is a mere 3 Hz, and that between [ɛ] and [æ] is 6 Hz. Both values are below 20 Hz, which causes poor intelligibility. Therefore, when male Mandarin speakers produce <hid> and <hayed>, and also <head> and <had>, the intelligibility level is poor.

Moderate masking occurs between the back vowels [u] (352Hz) and [ʊ] (382Hz) as well as between the low vowels [æ] (730) and [ʌ] (768) on the other hand. The F1 distance of 30 Hz between [u] and [ʊ] and the F1 distance of 38 Hz between [æ] and [ʌ], will cause questionable intelligibility. Therefore, when male Mandarin speakers produce <who’d> and <hood>, and also <had> and <hud>, questionable intelligibility would occur.

External masking analysis of ten males. A comparison of the vowels of male Mandarin participants and the adjacent vowels of male GAE speakers finds intelligibility problems in the front vowels [i] vs. [ɪ] vs. [e], as in the words <heed>, <hid> and <hayed>. The Mandarin participants’ [i] (362 Hz) moderately masks the GAE speakers’ [ɪ] (390 Hz). The acoustic distance between them is 28 Hz, which is within the range of questionable intelligibility. The F1 distance between the Mandarin-accented [ɪ] (413 Hz) and the GAE [e] (470 Hz) is 57 Hz. Therefore, these vowels only slightly mask each other, and the intelligibility level between them is above average. Meanwhile, the distance between the Mandarin participants' [e] (416 Hz) and GAE speakers' [ɪ] (390 Hz) is 26 Hz. Therefore, GAE listeners would have a hard time distinguishing between the words <heed>, <hid>, and <hayed> when male Mandarin speakers pronounce them.

External masking also occurs in the back vowels. the F1 distance between the participants' [ɔ] (674 Hz) and GAE speakers' [ɑ] (730 Hz) and also the participants' [o] (496 Hz) and GAE speakers' [ʊ] (440 Hz) are both 56 Hz. It means that the vowels slightly mask each other, and the intelligibility level is above average. However, the difference of participants' [ɑ] (580 Hz) and GAE [ɔ] (570 Hz) is only 10 Hz. Therefore, a GAE hearer is not likely to distinguish between the words <hod> and <hawed> when male Mandarin speakers say them.

The participants' low vowels [æ] (730 Hz) and the GAE [ɑ] (730Hz) completely mask each other. For this reason, it would not be possible for a GAE hearer to distinguish these vowels when listening to male Mandarin speakers. The participants' [ʌ] (768 Hz) moderately masks the GAE [ɑ] (730 Hz). The F1 distance between them is 38 Hz, which would likely cause questionable intelligibility for a GAE hearer.

Masking and Intelligibility Assessment of the Five Males with LOR<1

F1 information of five males with LOR<1. Table 2.3 provides the F1 information of the participants in this group and that of the male GAE speakers.

Table 2.3

F1 Values of Five Male Mandarin Speakers with LOR<1 and Male GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
male1<1	314	347	345	688	749	333	580	419	324	321	777
male2<1	334	384	379	670	640	373	629	597	458	384	790
male3<1	295	309	306	613	596	571	522	288	298	291	757
male4<1	630	726	423	761	729	550	805	473	326	337	819
male5 <1	478	494	750	733	756	715	752	575	470	454	952
St. Deviation	143	168	178	57	64	156	118	125	82	64	78
Participants' mean	410	452	441	693	694	508	658	470	375	357	819
GAE mean	270	390	476	530	660	730	570	497	440	300	640
Difference	140	62	35	163	34	222	88	27	65	57	179

According to Table 2.3, some participant vowels have an F1 distance of less than 60 Hz from GAE, meaning they are produced with optimal intelligibility. These vowels occur in the words <hayed>, <had>, <hoed>, and<who'd>.

The other vowels have an F1 distance of more than 60 Hz from GAE pronunciation. For these vowels, the participants' [i] (410 Hz) is 140 Hz greater than the GAE [i] (270 Hz), indicating that when the participants in this group produce the vowel [i], their mouths open more widely than GAE speakers. Similarly, the participants open their mouth wider than GAE speakers when they produce the vowels [ɪ], [ɛ], [ɔ], and [ʌ]. The F1 values of these vowels produced by the participants of this group are all greater than the GAE F1values. However, the F1 of the participants' [ʊ] (375 Hz) is 65 Hz smaller than GAE's [ʊ] (440 Hz). This means that when the participants of this group produce the vowel [ʊ], their mouths open less widely than those of GAE speakers.

F2 information of five males with LOR<1. Table 2.4 arranges the F2 values of the participants in this group and those of male GAE speakers.

Table 2.4

F2 Values of Five Male Mandarin Speakers with LOR<1 and Male GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
male1<1	2219	2141	2073	1742	1639	1467	949	1033	2068	1831	1282
male2<1	2207	2109	2151	1644	1527	805	972	940	833	764	1197
male3<1	2461	2327	2302	1841	1824	1212	952	1228	1398	840	1264
male4<1	1794	1661	2171	1656	1755	1364	1185	1476	1079	943	1089
male5 <1	2123	2163	1768	1784	1768	1243	1176	1178	1096	1051	1413
St. Deviation	241	249	199	84	119	252	122	205	476	430	119
Participants' mean	2161	2080	2093	1733	1703	1218	1047	1171	1295	1086	1249
GAE mean	2290	1990	2089	1840	1720	1090	840	910	1020	870	1190
Difference	129	90	4	107	17	128	207	261	275	216	59

Table 2.4 provides the F2 values of the five male participants with LOR<1 and that of GAE males. According to the information from the table, the participants produce words containing the vowels [ɔ], [o], [ʊ], and [u] with intelligibility problems. This is because the F2 distances between the participants' vowels and GAE vowels are more than 200 Hz. The F2 of these vowels produced by the participants are all smaller than the GAE F2s, indicating that when the participants produce these vowels, their tongues are more forward than those of GAE speakers.

The intelligibility of all other vowels is optimal because the F2 distance between those of the participants and those of GAE speakers F2 is less than 200 Hz.

Acoustic vowel space of five males with LOR<1. Figure 2.2 compares the acoustic vowel space of vowels produced by the five male participants with LOR<1 and GAE vowels.

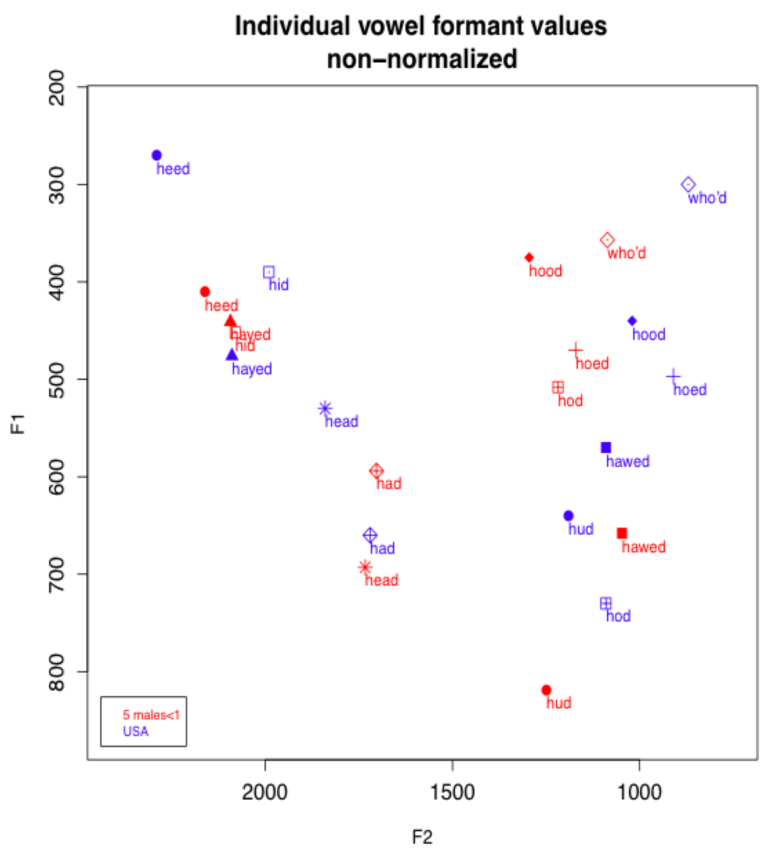

Figure **2.2** Acoustic Vowel Space of Five Male Participants with LOR<1 and Male GAE Speakers

Internal masking analysis of five males with LOR<1. The participants' front vowels [i] (410 Hz) and [ɪ] (452 Hz) slightly mask each other in terms of vowel height. The acoustic distance between them is 42 Hz. The intelligibility level is above average. So, when the five male Mandarin speakers with LOR<1 produce the words <heed> and <hid>, the intelligibility level is above the average.

Complete masking occurs between the vowels [ɪ] vs. [e], [ɛ] vs. [æ], and [u] vs. [ʊ]. The acoustic distance between [ɪ] (452 Hz) and [e] (441 Hz) is 11 Hz and that of [ɛ] (693 Hz) and [æ]

(694 Hz) is a mere 1 Hz. The acoustic distance between [u] (357 Hz) and [ʊ] (375 Hz) is 18 Hz. The acoustic distance between each of these vowel pairs is below 20 Hz, which cannot be detected by human beings (Ladefoged, 1996). For this reason, when the participants of this group produce the words that contain these vowels, it would cause poor intelligibility.

External masking analysis of five males with LOR<1. When comparing the adjacent vowels produced by the participants with LOR<1 and male GAE speakers, slight masking occurs between the F1 of the participants' [e] (441 Hz) and the GAE [ɪ] (390 Hz). The distance between them is 51 Hz, resulting in above-average intelligibility. However, unintelligibility cannot be completely eliminated because the F1 distance is still less than 60 Hz. In addition, the F1 distance between the participants' [i] (410Hz) and GAE's [ɪ] (390 Hz) is 20 Hz; the F1 distance between the participants' [ɪ] (452 Hz) and GAE [e] (476 Hz) is 24 Hz; the F1 distance between the participants' [ɛ] (693 Hz) and GAE [æ] is 33 Hz. The F1 distance between all the adjacent vowel pairs is within the range of moderate masking/ questionable intelligibility. Therefore, a GAE hearer would have difficulty distinguishing between the words <heed> and <hid>, <hid> and <hayed>, and also <head> and <had>, when the participants of this group pronounce them.

While masking also occurs in back vowels and low vowels. the only vowel pair that is likely to cause intelligibility problems is the participants' [o] and the GAE [ʊ]. The F1 of the participants' [o] is 470 Hz, and that of GAE speakers is 440 Hz. The difference between them is 30 Hz; thus, the F1s of these two vowels moderately mask each other. It would be difficult for a GAE hearer to distinguish between the words <hoed> and <hood> when the participants of this group pronounce them. Furthermore, slight masking occurs between the participants' [æ] (694Hz) and the GAE [ʌ] (640 Hz). Moderate masking occurs between the participants' [æ]

(694Hz) and the GAE [ɑ] (730 Hz). Therefore, when participants of this group pronounce the words <had>, <hud> and <hod>, the GAE hearers would have difficulty distinguishing the words.

Masking and Intelligibility Assessment of Five Males with LOR>1

F1 information of five males with LOR>1. This section focuses on the masking and intelligibility assessment of the participant subgroup whose LOR is more than one year. Table 2.5 provides the F1 information of the participants in this group and the F1 of male GAE speakers.

Table 2.5

F1 Values of Five Male Mandarin Speakers with LOR>1 and Male GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
male6>1	308	295	408	717	784	713	779	501	439	310	814
male7>1	307	342	393	735	757	422	605	416	321	348	770
male8>1	285	520	452	927	907	859	681	627	415	352	845
male9>1	336	375	312	671	699	805	696	569	359	334	374
male10>1	328	335	387	720	692	454	693	490	412	391	781
St. Deviation	20	87	51	100	87	201	62	81	48	30	194
Participants' mean	313	373	390	754	768	651	691	521	389	347	717
GAE mean	270	390	476	530	660	730	570	497	440	300	640
Difference	43	17	86	224	108	79	121	24	51	47	77

According to Table 2.5, some vowels of the participants and GAE speakers have an F1 difference of less than 60 Hz. These vowels include [i], [ɪ], [o], [ʊ], and [u]. Since an acoustic distance of less than 60 Hz causes optimal intelligibility; the participants of this group produce these vowels with optimal intelligibility.

However, some vowels of the participants and GAE speakers have an F1 difference of more than 60 Hz. For example, the participants' [e] (390 Hz) and the GAE [e] (476 Hz) have an F1 distance of 86 Hz. The smaller F1 value produced by the participants means that their mouths open less widely than those of GAE speakers. The vowels [ɛ], [æ], [ɑ], [ɔ], and [ʌ] produced by the participants and GAE speakers also have the F1 distances greater than 60 Hz. However, in these cases, the F1 values of vowels produced by participants are smaller than the F1s of GAE speakers. When the participants produce these vowels, their mouths open less widely than those of GAE speakers.

F2 information of five males with LOR>1. Table 2.6 provides the F2 information of five males with LOR>1 and GAE.

Table 2.6

F2 Values of Five Male Mandarin Speakers with LOR>1 and Male GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
male6>1	2284	305	2237	1963	1839	1081	1296	1067	1426	1099	1414
male7>1	2136	2044	2024	1687	1658	900	940	919	883	1013	1377
male8>1	2419	2151	2329	1703	1720	1296	1016	1840	1271	1066	1333
male9>1	2535	2383	2399	2016	1895	1501	1262	1336	1281	945	1107
male10>1	2152	2116	2012	1665	1675	915	1013	1384	1239	1081	1218
St. Deviation	172	845	176	168	104	258	162	353	202	62	126
Participants' mean	2305	1800	2200	1807	1757	1139	1105	1309	1220	1041	1290
GAE mean	2290	1990	2089	1840	1720	1090	840	910	1020	870	1190
Difference	15	190	111	33	37	49	265	399	200	171	100

Based on the information of Table 2.6, the participants of this group produce most vowels similarly to GAE, demonstrated by F2 distances equal to or less than 200 Hz. The only two vowels that are different are [ɔ] and [o]. The F2 distance between the participants' [ɔ] (1105 Hz) and the GAE [ɔ] (840 Hz) is 265 Hz; and that between the participants' [o] (1309 Hz) and the GAE [o] (910 Hz) is 399 Hz. The participants' F2 values for these two vowels are both greater than those of the GAE male speakers. This indicates that when participants of this group produce the vowels [ɔ] and [o], their tongues are more forward than those of GAE speakers.

Acoustic vowel space of five males with LOR>1. Figure 2.3 below provides the visualization acoustic vowel space as produced by male Mandarin speakers with LOR>1 and male GAE speakers.

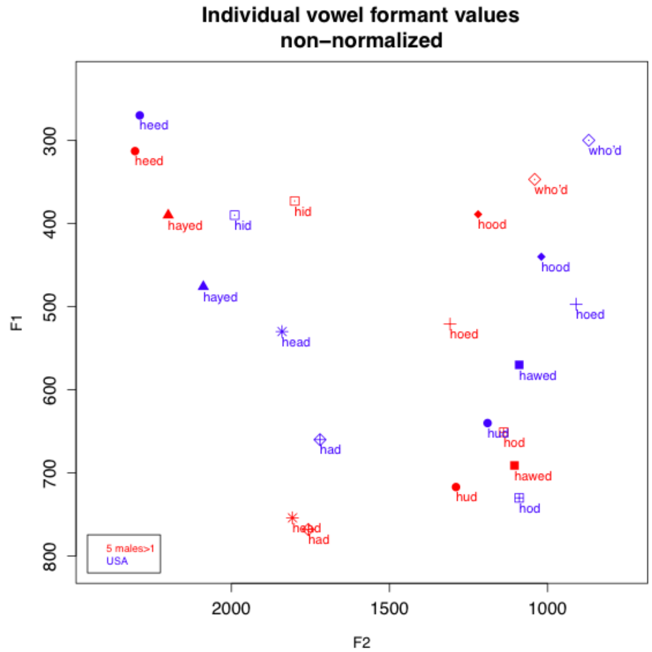

Figure **2.3** Acoustic Vowel Space of Five Male Participants with LOR>1 and Male GAE Speakers

Internal masking analysis of five males with LOR>1. Slight masking occurs between the vowels [i] vs. [ɪ], [u] vs. [ʊ]; and [æ] vs. [ʌ]. The F1 distance between [i] (313 Hz) and [ɪ] (373 Hz) is 60 Hz; that between [u] (347 Hz) and [ʊ] (389 Hz) is 42 Hz; and that between [æ] (768 Hz) and [ʌ] (717 Hz) is 51 Hz. When the participants of this group produce these vowels, the intelligibility level is above average. However, unintelligibility issues cannot be eliminated because the acoustic distances are below 60 Hz.

The vowel [ɔ] (691 Hz) moderately masks the vowel [ɑ] (651 Hz) as the F1 distance between them is 40 Hz. When the participants of this group produce the words <hawed> and <hod>, intelligibility is questionable.

The front vowel pairs [ɪ] vs. [e], and [ɛ] vs. [æ] completely mask each other. The F1 distance between [ɪ] (373 Hz) and [e] (390 Hz) is 17 Hz, and the acoustic distance between [ɛ] (754Hz) and [æ] (768 Hz) is 14 Hz. Because these two values are both below the minimal perceptual value of 20 Hz, a GAE hearer cannot perceive any difference when the participants of this group produce the words <hid> and <hayed>, or <head> and <had>.

External masking analysis of five males with LOR>1. By comparing and contrasting the participants' vowels with GAE vowels, it was found that masking occurs mostly in front vowels and back vowels.

First, slight masking occurs between participants' [o] (521 Hz) and the GAE [ɔ] (570 Hz), and participants' [ʌ] (717 Hz) and the GAE [æ] (660 Hz). The acoustic distance between [o] and [ɔ] is 49 Hz, and the acoustic distance between [ʌ] and [æ] is 57 Hz. The intelligibility level is above average.

Moderate masking occurs between participants' [ɔ] (691 Hz) and the GAE [ɑ] (730 Hz), and participants' [æ] (768 Hz) and the GAE [ɑ] (730 Hz). The acoustic distance between [ɔ] and [ɑ] is 39 Hz, and the acoustic distance between [æ] and [ɑ] is 38 Hz, which would cause questionable intelligibility.

Complete masking occurs between participants' [e] (390 Hz) and the GAE [ɪ] (390 Hz), participants' [ʌ] (717 Hz) and the GAE [ɑ] (730 Hz), participants' [ɑ] (651 Hz) and the GAE [æ] (660 Hz), participants' [ɑ] (651 Hz) and the GAE [ʌ] (640 Hz). Because of the acoustic distance of below 20 Hz, when the participants of this group produce these vowel pairs, the intelligibility level is poor.

Conclusion

Both of the participants with LOR<1 and the participants with LOR>1 have the intelligibility problem when they produce the vowel [i] and [ɪ]. Both of the two subgroups have the above average intelligibility. There is no significant difference between the different LOR. Meanwhile, both of the two subgroups produce the vowel [ɪ] vs. [e] and [ɛ] vs. [æ] with poor intelligibility. Therefore, LOR has no beneficial effects on intelligibility on these vowels.

The intelligibility problem occurs between the words containing the vowels [u] and [ʊ]. However, the GAE hearers would have more difficulties distinguishing these two vowels produced by the participants with LOR<1 than those with LOR>1. Therefore, it can be postulated that the LOR has beneficial effect on the intelligibility between [u] and [ʊ].

The intelligibility problem between the vowels [æ] and [ʌ] is only caused by the participants with LOR>1. So, LOR has no beneficial effect on intelligibility between the vowels [æ] and [ʌ].

Chapter III. Masking and Intelligibility Assessment of Female Mandarin Speakers

Chapter Introduction

This chapter assesses the masking degrees and intelligibility levels of vowels produced by female Mandarin speakers. Similar to the previous chapter, the first two formants of female Mandarin speakers' vowels are contrasted with those of female GAE speakers in the acoustic vowel space. The F1 and F2 values of GAE females are taken from Peterson and Barney (1952, p.183). The masking/intelligibility threshold is also used in this chapter for assessing the masking and intelligibility levels.

The current chapter includes four sections. In the first part, the F1 and F2 values of the ten female participants are provided to investigate which Mandarin-accented vowel(s) is/are similar to GAE, and which one(s) is/are not. Internal and external masking and intelligibility levels of the ten females' vowels are assessed. The second and third parts of the chapter provide the same analyses of the two subgroups of LOR ±1. Finally, the last part correlates the LOR with the female Mandarin speakers' vowel intelligibility.

Masking and Intelligibility Assessment of Ten Female Participants

F1 information of ten female participants. Table 3.1 provides the F1 values of the ten female participants and those of the female GAE speakers. The acoustic threshold of 60 Hz is used for assessing vowel similarity.

Table 3.1

F1 Values of Ten Female Mandarin Speakers and Female GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
female1<1	387	440	738	815	862	692	738	927	414	412	886
female2<1	376	376	534	940	945	932	923	439	421	426	947
female3<1	335	332	359	597	522	522	706	426	386	363	591
female4<1	352	400	434	660	767	433	633	477	398	403	900
female5<1	423	437	599	852	953	938	985	826	521	597	863
female6>1	353	463	477	818	798	793	816	602	420	428	893
female7>1	273	372	479	803	849	783	886	504	425	419	882
female8>1	407	897	463	1002	964	490	783	527	539	450	996
female9>1	916	336	451	866	858	777	788	566	376	335	1048
female10>1	387	441	517	769	794	604	793	528	464	488	863
St. Deviation	179	164	104	119	129	179	104	166	55	72	120
Participants' mean	421	449	505	812	831	696	805	582	436	432	887
GAE mean	310	430	536	610	860	850	590	555	470	370	760
Difference	111	19	31	202	29	154	215	27	34	62	127

According to the information above, female Mandarin speakers produce some vowels similarly to GAE vowels because the F1 distance for those vowels are less than 60 Hz. For example, the F1 of the Mandarin-accented [ɪ] is 449 Hz, and the F1 of GAE [ɪ] is 430 Hz. The F1 distance between them is 19 Hz. Similarly, the female Mandarin speakers' vowels [e], [æ], [o] and [ʊ] also have an F1 distance of less than 60 Hz compared to GAE. Therefore, female Mandarin speakers produce these vowels with good intelligibility.

The other Mandarin-accented vowels have an F1 distance greater than 60 Hz. Production of those vowels by female Mandarin speakers would cause intelligibility problems. For instance, the F1 of the Mandarin-accented [ɑ] (696 Hz) and the GAE [ɑ] (850 Hz) has the distance of 154 Hz. The Mandarin-accented [ɑ] has a smaller F1 value than the GAE [ɑ], meaning that when producing the vowel [ɑ], female Mandarin speakers open their mouths less widely than do female GAE speakers.

Some Mandarin-accented vowels are produced differently from GAE vowels because female Mandarin speakers open their mouths more widely than GAE speakers. For example, the F1 of [i] produced by the female Mandarin speakers (421 Hz) is 111 Hz greater than that of GAE (310 Hz). The same is true for [ɛ], [ɔ], [u], and [ʌ].

F2 information of ten females. Table 3.2 below shows the F2 information of ten Mandarin-speaking females and GAE female speakers. The acoustic distance threshold of 200 Hz is used for assessing if a vowel is produced similarly.

Table 3.2

F2 Values of Ten Female Mandarin Speakers and Female GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
female1<1	2653	2325	1157	1972	1573	1165	1157	1132	1145	1186	1635
female2<1	2412	2407	2334	1969	1964	1539	1540	1022	925	978	1638
female3<1	2456	2436	2324	1840	1793	1128	1332	1046	928	962	1710
female4<1	2651	2573	2468	2127	1753	1150	1120	1307	938	852	1548
female5<1	2526	2556	1894	1693	1607	1376	1410	1191	1113	1127	1274
female6>1	2768	2563	2483	1860	1882	1188	1198	946	770	765	1481
female7>1	2495	2479	2415	1942	1865	2368	1382	958	862	869	1466
female8>1	2810	2263	2664	2102	2229	1159	1332	1130	1083	1043	1783
female9>1	2515	2482	2409	1961	1904	1229	1159	1044	875	837	1701
female10>1	2800	2630	2525	2146	1946	1205	1334	1119	1310	1468	1661
St. Deviation	148	116	439	141	188	379	134	110	163	209	150
Participants' mean	2609	2471	2267	1961	1852	1351	1296	1090	995	1009	1590
GAE mean	2790	2480	2530	2330	2050	1220	920	1035	1160	950	1640
Difference	181	9	263	369	198	131	376	55	165	59	50

The female Mandarin speakers produce most vowels similarly to GAE speakers, except for [e], [ɛ] and [ɔ]. The F2 distance of these vowels is more than 200 Hz. For example, the F2 distance between the Mandarin-accented [e] (2267 Hz) is 263 Hz smaller the GAE [e] (2530 Hz). This demonstrates that when female Mandarin speakers produce the vowel [e], their tongues retract more than those of GAE speakers. Similarly, the F2 of vowel [ɛ] produced by female

Mandarin speakers is 1961 Hz, and that of GAE speakers is 2330 Hz, a distance of 369 Hz, showing that the female Mandarin speakers' tongues are more back than those of female GAE speakers. On the other hand, the female Mandarin speakers' tongues are more forward than GAE speakers when producing the vowel [ɔ]: The Mandarin-accented [ɔ] (1296 Hz) is 376 Hz greater than the GAE [ɔ] (920 Hz).

The other vowels have F2 distances smaller than 200 Hz. Because female Mandarin speakers produce these vowels similarly to GAE speakers. Notably, Mandarin-accented [ɪ] (2471 Hz) and the GAE [ɪ] (2480 Hz) have a difference of only 9 Hz. This means that female Mandarin speakers produce this vowel very similarly to GAE speakers.

Acoustic vowel space of ten females. The acoustic vowel space Figure 3.1 pictures the vowel production of the ten female participants and female GAE speakers.

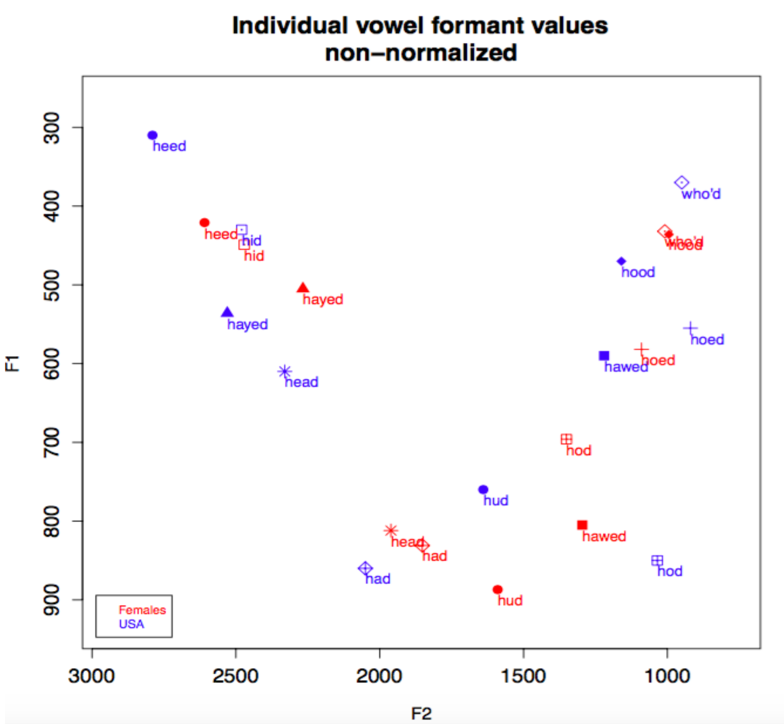

Figure **3.1** Acoustic Vowel Space of Ten Female Participants and Female GAE Speakers

Internal masking analysis of ten females. As shown by Table 3.1, internal masking occurs when the female participants produce some of the vowels. For example, slight masking occurs between the vowels [ɪ] (449 Hz) and [e] (505 Hz). The F1 distance between them of 56 Hz would cause above average intelligibility. The low vowels [æ] (831 Hz) and [ʌ] (887 Hz) distanced by 56 Hz, also slightly mask each other.

The vowels [i] (421 Hz) and [ɪ] (449 Hz) would likely cause questionable intelligibility when the female participants produce them because the F1 distance between them is only 28 Hz.

Complete masking occurs between the vowel pair [ɛ] and [æ] and also between [u] and [ʊ]. The distance between [ɛ] (812 Hz) and [æ] (831 Hz) is 19 Hz; and the distance between [ʊ] (436Hz) and [u] (432 Hz) is merely 4 Hz. Both distances are below the minimal perceptual frequency value of 20 Hz. Thus, when the female participants produce the words <head> and <had>; and also <who'd> and <hood>, it would cause poor intelligibility.

External masking analysis of ten females. Slight masking occurs between the Mandarin-accented [ɛ] (812 Hz) and the GAE [æ] (860 Hz); and also the Mandarin-accented [ɔ] (805 Hz) and the GAE [ɑ] (850 Hz). The F1 distance between [ɛ] and [æ] is 48 Hz; and the F1 distance between [ɔ] and [ɑ] is 45 Hz. Therefore, it would be difficult for a GAE hearer to distinguish the words <head>and <had> and also <hawed> and <hod> when the female Mandarin speakers pronounce them.

The Mandarin-accented [u] (432 Hz) and the GAE [ʊ] (470 Hz) have the F1 distance of 38 Hz. The Mandarin-accented [ʌ] (887 Hz) and the GAE [ɑ] (850 Hz) have the distance of 37 Hz. Moreover, the distance between the Mandarin-accented [ʌ] (887 Hz) and the GAE [æ] (860 Hz) is 27 Hz. These distance values are within the range of moderate masking and questionable intelligibility level. So, when the female Mandarin speakers pronounce the words <who’d> and <hood> and also <hud> and <hod>, the GAE hearers would have a hard time distinguishing them.

Complete masking occurs only between the Mandarin-accented [o] (582 Hz) and GAE’s [ɔ] (590 Hz). The distance between them is merely 8 Hz. This means that when female Mandarin speakers produce these vowels, a GAE hearer would be unlikely to perceive any difference between them.

Masking and Intelligibility Assessment of Five Females with LOR<1

F1 information of five females with LOR<1. Table 3.3 below shows the F1 information of both the five female participants with LOR<1 and the F1 of female GAE speakers.

Table 3.3

F1 Values of Five Females with LOR<1 and Female GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
female1<1	387	440	738	815	862	692	738	927	414	412	886
female2<1	376	376	534	940	945	932	923	439	421	426	947
female3<1	335	332	359	597	522	522	706	426	386	363	591
female4<1	352	400	434	660	767	433	633	477	398	403	900
female5<1	423	437	599	852	953	938	985	826	521	597	863
St. Deviation	34	45	147	141	178	231	150	238	54	91	141
Participants' mean	375	397	533	773	810	703	797	619	428	440	837
GAE mean	310	430	536	610	860	850	590	555	470	370	760
Difference	65	33	3	163	50	147	207	64	42	70	77

The vowels [ɪ], [e], [æ] and [ʊ] are produced similarly by the speakers of this group compared to GAE speaking females distanced by less than 60 Hz. Particularly, the distance of the female Mandarin speakers’ [e] (533 Hz) and the GAE [e] (536 Hz) is only 3 Hz.

On the other hand, the other vowels have a distance of more than 60 Hz when compared between the two groups. The female Mandarin speakers' [i] (375 Hz) is 65 Hz greater than the GAE [i] (310 Hz), because when producing the vowel [i], the participants of this group open their mouths more widely than GAE speakers. Likewise, the participants open their mouths more widely when they produce the vowels [ɛ], [ɔ], [o], [u], [ʌ].

The female Mandarin speakers' [ɑ] (703 Hz) and the GAE [ɑ] (850 Hz) also have a distance of more than 60 Hz. However, in this case the Mandarin-accented [ɑ] is 147 Hz smaller than the GAE [ɑ]. This means that when producing the vowel [ɑ], the participants of this group open their mouths less widely than do GAE speakers.

F2 information of five females with LOR<1. The F2 values of the female speakers with LOR<1 and that of the female GAE speakers are provided below:

Table 3.4

F2 Values of Five Females with LOR<1 and Female GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
female1<1	2653	2325	1157	1972	1573	1165	1157	1132	1145	1186	1635
female2<1	2412	2407	2334	1969	1964	1539	1540	1022	925	978	1638
female3<1	2456	2436	2324	1840	1793	1128	1332	1046	928	962	1710
female4<1	2651	2573	2468	2127	1753	1150	1120	1307	938	852	1548
female5<1	2526	2556	1894	1693	1607	1376	1410	1191	1113	1127	1274
St. Deviation	110	104	536	163	157	180	175	115	110	134	170
Participants mean	2540	2459	2035	1920	1738	1272	1312	1140	1010	1021	1561
GAE mean	2790	2480	2530	2330	2050	1220	920	1035	1160	950	1640
Difference	250	21	495	410	312	52	392	105	150	71	79

Based on the information in Table 3.4, it can be deduced that when the participants of this group produce the vowel [ɔ], their tongues move more forward than those of female GAE speakers., as the F2 of the participants' [ɔ] (1312 Hz) is 392 Hz greater than the GAE [ɔ] (920 Hz).

The participants of this group also produce the vowels [i], [ɪ], [e], [ɛ], and [æ] differently from GAE speakers. The participants' F2 values of these vowels are all smaller than those of GAE speakers by more than 200 Hz. Clearly, when the participants of this group produce these vowels, their tongues are more back than those of GAE speakers.

Except for the vowels noted above, the participants of this group produce the other vowels similarly to GAE speakers, with a distance of less than 200 Hz.

Acoustic vowel space of five females with LOR<1. The F1 and F2 values of each vowel produced by both the speakers of this group and the female GAE speakers are plotted together in the acoustic vowel space below:

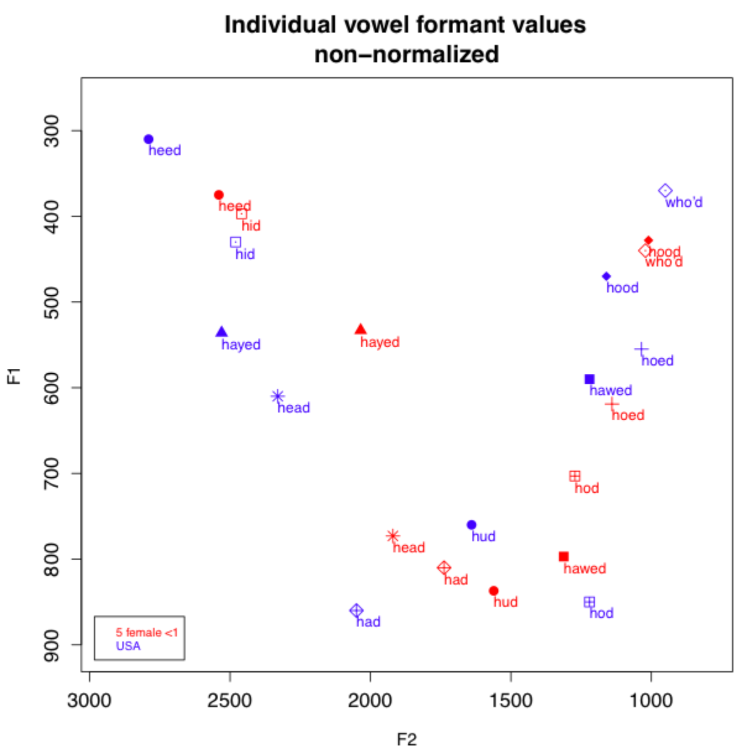

Figure **3.2** Acoustic Vowel Space of Five Female Participants with LOR<1 and Female GAE Speakers

Internal masking analysis of five females with LOR<1. According to the acoustic vowel space, some moderate and some complete masking occur in the participants' vowel production. For instance, the vowel [i] (375 Hz) moderately masks [ɪ] (397 Hz) because the distance between them is 22 Hz. Also, the distance between [ɛ] (773 Hz) and [æ] (810 Hz) is 37 Hz; the distance between [æ] (810 Hz) and [ʌ] (837 Hz) is 27 Hz. These distances are all within the range of moderate masking and questionable intelligibility.

The back vowel [u] (440 Hz) masks [ʊ] (428 Hz) completely because the distance between them is a mere 12 Hz. Hence, when the participants of this group produce the vowels [u] and [ʊ], the differences would be indistinguishable.

External masking analysis of five females with LOR<1. Moderate masking occurs between Mandarin-accented [ɔ] (797 Hz) and the GAE [ɑ] (850 Hz) because the distance between them is 53 Hz. Similarly, moderate masking also occurs between the participants' [o] (619 Hz) and the GAE [ɔ] (590 Hz); the participants' [æ] (810 Hz) and the GAE [ɑ] (850 Hz); and also the participants' [ʌ] (837 Hz) and the GAE [æ] (860 Hz). Therefore, when the participants of this group produce these vowels, GAE hearers would have a hard time distinguishing between them.

The participants' [ʌ] (837 Hz) completely masks the GAE [ɑ] (850 Hz) because the distance between them is only 13 Hz. Thus, it is not likely that a GAE hearer would perceive any difference when the participants of this group produced <hud> and <hod>.

Masking and Intelligibility Assessment of Five Females with LOR>1

F1 information of five females whose LOR>1. Table 3.5 provides the F1 values of the five female Mandarin speakers whose LOR is more than one year, and also the F1 values of female GAE speakers.

Table 3.5

F1 Values of Five Females with LOR>1 and female GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
female6>1	353	463	477	818	798	793	816	602	420	428	893
female7>1	273	372	479	803	849	783	886	504	425	419	882
female8>1	407	897	463	1002	964	490	783	527	539	450	996
female9>1	916	336	451	866	858	777	788	566	376	335	1048
female10>1	387	441	517	769	794	604	793	528	464	488	863
St. Deviation	256	227	25	91	69	136	43	39	61	56	81
Overall mean	467	502	477	852	853	689	813	545	445	424	936
GAE mean	310	430	536	610	860	850	590	555	470	370	760
Difference	157	72	59	242	7	161	223	10	25	54	176

According to the information above, some participant and GAE vowels have an F1 difference of less than 60 Hz. This means that the participants produce these vowels similarly to GAE speakers. These vowels include [e], [æ], [o], [ʊ], and [u].

The other female Mandarin vowels are produced differently than corresponding GAE vowels, with distances of more than 60 Hz. For example, the participants'[i] (467 Hz) is 157 Hz higher than GAE's [i] (310 Hz). This demonstrated that when producing the vowel [i], the participants of this group open their mouths more widely than do the female GAE speakers. Also, the female participants open their mouths more widely when producing the vowels [ɪ], [ɛ], [ɔ], and [ʌ]. However, when participants produce the vowel [ɑ], their mouths open less widely than those of female GAE speakers. Thus, the participants' [ɑ] (689 Hz) is 161 Hz smaller than that of the GAE [ɑ] (850 Hz).

F2 information of five females with LOR>1. Table 3.6 shows in detail the F2 information of both the female participants with LOR>1 and the female GAE speakers.

Table 3.6

F2 Values of Five Females with LOR>1 and Female GAE Speakers

Words	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels	[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
female6>1	2768	2563	2483	1860	1882	1188	1198	946	770	765	1481
female7>1	2495	2479	2415	1942	1865	2368	1382	958	862	869	1466
female8>1	2810	2263	2664	2102	2229	1159	1332	1130	1083	1043	1783
female9>1	2515	2482	2409	1961	1904	1229	1159	1044	875	837	1701
female10>1	2800	2630	2525	2146	1946	1205	1334	1119	1310	1468	1661
St. Deviation	158	138	104	119	151	525	97	86	217	283	139
Participants'' mean	2678	2483	2499	2002	1965	1430	1281	1039	980	996	1618
GAE mean	2790	2480	2530	2330	2050	1220	920	1035	1160	950	1640
Difference	112	3	31	328	85	210	361	4	180	46	22

By comparing the different values, it is obvious that the participants produce most vowels similarly to GAE speakers, with differences of less than 200 Hz, except for the vowels [ɛ], [ɑ], and [ɔ].

When the participants produce the vowel [ɛ], their mouths open less widely than those of GAE speakers, as shown by the fact that the participants' [ɛ] (2002 Hz) is 328 Hz smaller than the GAE [ɛ] (2330 Hz). However, the participants' mouths open more widely than those of GAE speakers when they produce the vowels [ɑ] and [ɔ]: The participants' [ɑ] (1430 Hz) is 210 Hz greater than the GAE [ɑ] (1220 Hz), and the participants' [ɔ] (1281 Hz) is 361 Hz greater than GAE's [ɔ] (920 Hz).

Acoustic vowel space of five females with LOR>1. The F1 and F2 values are plotted together in the acoustic vowel space below, showing how vowels are produced by the participants of this group and GAE speakers.

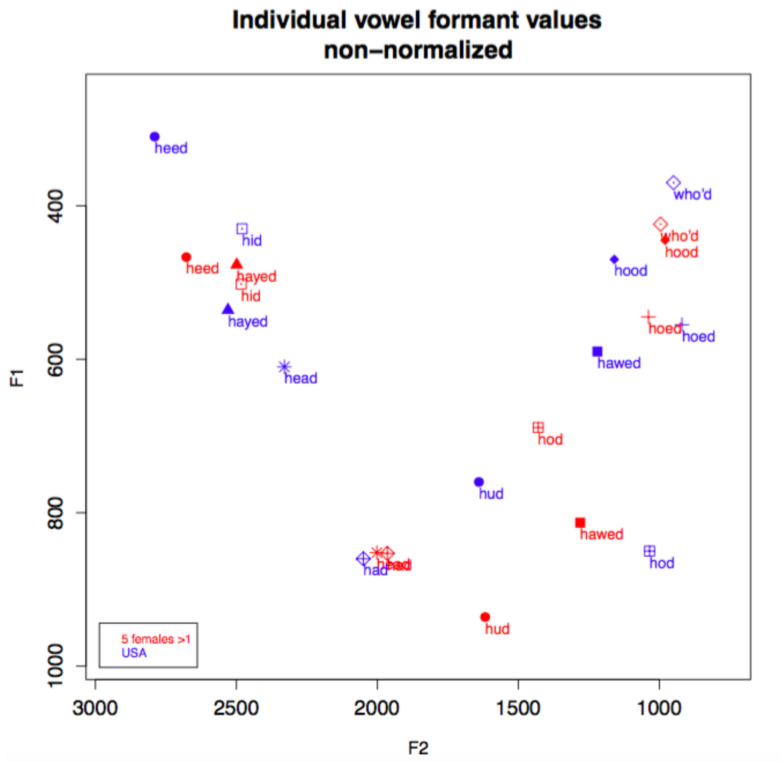

Figure **3.3** Acoustic Vowel Space of Five Female Participants with LOR>1 and Female GAE Speakers

Internal masking analysis of five females with LOR>1. Moderate masking occurs between some vowels produced by the participants of this group. For example, the F1 of the vowel [i] is 467 Hz, the F1 of [ɪ] is (502 Hz). The distance between them is 35Hz. Therefore, the intelligibility level is questionable. The vowel [ɪ] (502 Hz) moderately masks [e] (477 Hz) because the distance between them is 25 Hz. The vowel [ʊ] (445 Hz) also moderately masks [u] (424 Hz) because the distance between them is 21 Hz.

The vowel [ɛ] (852 Hz) has a distance of merely 1 Hz from the vowel [æ] (853 Hz). Since the distance between them is below 20 Hz, so when the participants of this group produce the words <head> and <had>, the difference would be indistinguishable.

External masking analysis of five females with LOR>1. Slight masking occurs between the participants' [e] (477 Hz) and the GAE [ɪ] (430 Hz). The F1 difference of 47 Hz enables above average intelligibility when the participants produce these two vowels. In addition, the F1 distance between the participants' [o] (545 Hz) and the GAE [ɔ] (590 Hz) is 45 Hz. The F1 distance between the participants' [u] (424 Hz) and the GAE [ʊ] (470 Hz) is 21 Hz. These distance values are all within the range of slight masking and above average intelligibility.

Moderate masking also occurs between the vowels produced by the participants of this group and those produced by GAE speakers. For example, the participants' [i] (467 Hz) and the GAE [ɪ] (430 Hz) moderately mask each other because of the F1 distance of 37 Hz. Similarly, with a distance of 34 Hz, the participants' [ɪ] (502 Hz) and the GAE [e] (536 Hz) moderately mask each other. Because of a distance of 37 Hz, the participants' [ɔ] (813 Hz) moderately masks the GAE [ɑ] (850 Hz). Therefore, when the speakers produce these vowels, a GAE hearer would have difficulty distinguishing them.

The difference between participants'[æ] (853 Hz) and the GAE [ɑ] (850Hz) is a mere 3 Hz. Therefore, when the participants of this group produce the words <head> and <hod>, the GAE hearers would not be likely to perceive any difference between them.

Conclusion

Female Mandarin speakers tend to raise the English vowels instead of lowering them. There are five vowels being raised, which are [i], [ɛ], [ɔ], [u], and [ʌ]. Only the vowel [ɑ] is lowered. The vowels [e], [ɛ], and [ɔ] are centralized by female Mandarin speakers.

Both subgroups of female Mandarin speakers raise the vowels [i], [ɛ], [ɔ], and [ʌ], while the vowels [o] and [u] are raised only by the subgroup with LOR<1. Only the subgroup with

LOR>1 raises [ɪ]. In terms of vowel backness, the vowels [ɔ] and [ɛ] are centralized by both subgroups. [ɑ] is fronted only by the subgroup with LOR>1. The vowels [i], [e], and [æ] are centralized only by the subgroup with LOR<1.

When comparing vowel intelligibility issues of the two subgroups, the data shows that the vowels [æ] vs. [ʌ] produced by the speakers with LOR<1 have questionable intelligibility. However, intelligibility is optimal for these vowels when produced by speakers with LOR>1. In this case, LOR has a beneficial effect on vowel intelligibility.

Nevertheless, both subgroups produce the vowels [i] vs. [ɪ], [u] vs. [ʊ], and [ɛ] vs. [æ] with intelligibility problems. In addition, the vowels [ɪ] vs. [e] are produced with intelligibility problems by the speakers with LOR>1. The intelligibility of these two vowels produced by those with LOR<1 is optimal. This shows that LOR has no significant effect on vowel intelligibility.

Chapter IV. Pedagogical Implications and Applications

Chapter Introduction

This chapter focuses on investigating the pedagogical implications and applications of the acoustic vowel space of all the participants in this study. The analyses mainly include two aspects. One is the analysis of the Mandarin-accented vowels which would cause intelligibility problems. The other is the analysis of the phonological processes affecting the vowels produced by the Mandarin speakers. Some pedagogical suggestions are also provided in this chapter. These analyses give insight into teaching English vowels to Mandarin speakers.

Acoustic Vowel Space of All Participants

Data of male and female Mandarin speakers has been separately compared and contrasted with that of GAE speakers in the previous chapters. In this chapter, the data of the male participants is contrasted with the data of the female participants. The first two formants of the participants are shown in Table 4.1:

Table 4.1

F1 and F2 Values of All Participants

Words		heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
Vowels		[i]	[ɪ]	[e]	[ɛ]	[æ]	[ɑ]	[ɔ]	[o]	[ʊ]	[u]	[ʌ]
Males	F1	362	413	416	724	730	580	674	496	382	352	768
	F2	2233	1940	2147	1770	1730	1178	1076	1240	1257	1063	1269
Females	F1	421	449	505	812	831	696	805	582	436	432	887
	F2	2609	2471	2267	1961	1852	1351	1296	1090	995	1009	1590

The F1 and F2 values of all participants are further plotted together in the same acoustic vowel space (Figure 4.1). In order to plot the values of different genders together, the vowels first need to be normalized. By choosing normalization with Telsur G, it is possible to eliminate variation caused by physiological differences among speakers (Thomas & Kendall, 2006). That is, the gender difference is able to be eliminated so that the focus is only on the vowels.

The acoustic vowel space plays an important role in intuitively presenting the English learners' vowel pronunciation. As Ladefoged (2001) asserts "Vowel charts provide an excellent way of comparing different dialects of a language. This kind of plot arranges in a similar way to the vowels in the IPA vowel chart." For pedagogical purposes, we recommend applying the acoustic vowel space information not only to Mandarin English classes, but also to other ESL classes. By doing this, students would have the opportunity to observe how they produce the vowels, and also how their vowels are produced similarly/differently compared to native pronunciation. This also relates to the Noticing Hypothesis, which asserts that noticing the gap between a learner's pronunciation and native pronunciation is important in acquiring L2 competency.

Figure 4.1 displays the acoustic vowel space of all participants. It provides the visualization of how the 11 English vowels are produced by Mandarin speakers.

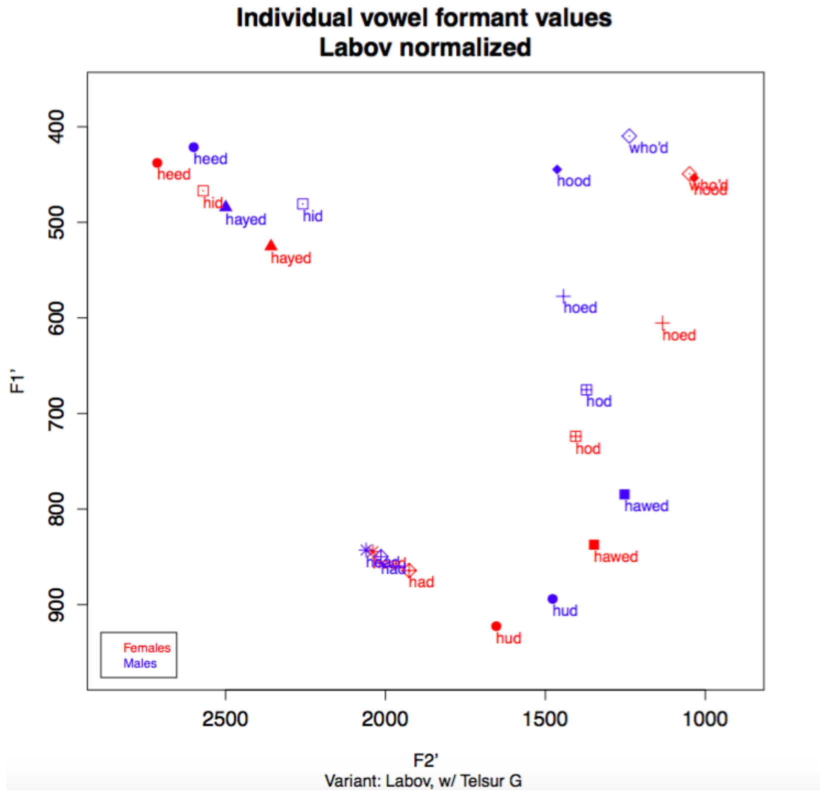

Figure **4.1** Acoustic Vowel Space of Ten Male Participants and Ten Female Participants

Vowel Pairs that Affect Intelligibility

According to the information showing acoustic vowel space above, the vowels [ɪ] vs. [e], [u] vs. [ʊ], and [ɛ] vs. [æ] are most likely to cause intelligibility problems when Mandarin speakers produce them. These vowel pairs should be given priority in English classes of Mandarin-speaking students background in order to improve their intelligibility.

Masking between [ɪ] and [e]. The female Mandarin-accented [ɪ] (449 Hz) overlaps male Mandarin-accented [e] (416 Hz) in the acoustic space. The acoustic distance between them is 33Hz. So the masking level between them is moderate, and would be likely to cause questionable intelligibility when Mandarin speakers produce these two vowels. Meanwhile, unintelligibility problems can be gauged by relying on the Relative Functional Load (RFL) for pedagogical purposes. Since the RFL of [ɪ] and [e] is 80%, intelligibility would be threatened by of the overlapping of these vowels. (See Appendix A for the RFL of related contrasting pairs of vowels in English; see Appendix B for the RFL and intelligibility level threshold.). In order to improve the intelligibility between [ɪ] and [e], the minimal pairs in table 4.2 below can be used for practicing in Mandarin English class.

Table 4.2

Minimal Pairs Containing Vowels [ɪ] and [e]

[ɪ]	hid	kiss	sit	pin	pill	sick	mix	lick	hill	miss
[e]	hayed	case	sate	pain	pale	sake	makes	lack	hail	mace

Masking between [u] and [ʊ]. The vowels [u] (432 Hz) for females and [ʊ] (436 Hz) for females should also be addressed when teaching a Mandarin English class because of the overlap between them. The F1 distance between them is only 4 Hz. However, intelligibility problems between [u] and [ʊ] are not as serious as for the previous vowel pairs because the RFL of [u] and [ʊ] is only 7%. To improve the production of these vowels, the minimal pairs in Table 4.3 are suggested for practice with Mandarin students.

Table 4.3

*Minimal Pairs Containing Vowels [*u*] and [ʊ]*

[u]	who'd	gooey	fool	pool	suit	boot	wooed	cooed	shoed	stewed
[ʊ]	hood	goody	full	pull	soot	book	wood	could	should	stood

Masking between [ɛ] and [æ]. The vowels [ɛ] (724 Hz) and [æ] (730 Hz) produced by male Mandarin speakers overlap each other because their F1 distance is only 6 Hz. Meanwhile, these vowels produced by female Mandarin speakers also overlap each other (815 Hz for [ɛ]; 831 Hz for [æ]) because the F1 distance between them is only 16 Hz. Since the RFL of [ɛ] and [æ] is

53%, serious intelligibility problems occur when Mandarin speakers produce the words such as <head> and <had> containing these vowels. The minimal pairs below can be used for pedagogical purposes.

Table 4.4

Minimal Pairs Containing Vowels [ɛ] and [æ]

[ɛ]	head	bed	beg	bend	blend	men	kettle	lend	temper	set
[æ]	had	bad	bag	band	bland	man	cattle	land	tamper	sat

Phonological Processes

The vowels produced by Mandarin speakers are also affected by phonological processes. A phonological process is a systematic change that affects classes of sounds or sound sequences and results in simplification of production (Koffi, 2015). On the basis of the information from Figure 4.1, vowel merging occurs between the vowels [ɛ] and [æ]. Meanwhile, the vowel [ɑ] is raised, while the vowels [ɛ] and [ɔ] are lowered.

Raised vowels. According to the acoustic vowel space of Figure 4.1, the low vowel [ɑ] is raised by Mandarin speakers. This indicates that when Mandarin speakers produce [ɑ], their mouths open less widely than expected. Thus, when teaching the pronunciation of words containing the vowel [ɑ], students should be asked to open their mouths more widely.

Lowered vowels. On the other hand, the mid vowels [ɛ] and [ɔ] are lowered by Mandarin speakers. Students with a Mandarin background should be taught to open their mouths less widely when they produce words containing these vowels, such as <head>, and <hawed>.

The lack of mid-fronted vowels. Teachers of English to Mandarin speakers should also be aware of the the absence of mid-front vowels in Mandarin English instructors. Since there are no mid-front vowels in the Mandarin vowel system, it is a difficult vowel category for Mandarin speakers to acquire. Therefore, Mandarin English teachers should put emphasis on the pronunciation of the English vowels [e] and [ɛ].

Noticing Hypothesis

It is always important for the participants of this study, and also for other language learners to be aware of their vowel pronunciation and vowel intelligibility. The Noticing Hypothesis highlights the importance of the awareness. The Noticing Hypothesis has existed for about two decades and continues to generate experimental studies and suggestions for L2 pedagogy. Schmidt notes that input does not become intake for language learning unless it is noticed, that is, consciously registered (Schmidt, 1990, 2001). As Baars (1997) puts it, “Paying attention, becoming conscious of some material, seems to be the sovereign remedy for learning anything ... It is the universal solvent of the mind” (Baars 1997, p. 304). If language learners want to acquire L2 competency, particularly in difficult areas such as pronunciation, they must first “notice the gap” between their speech and native pronunciation (Gass & Selinker, 2008, p. 248). Consequently, it is suggested that not only Mandarin English learners, but also other ESL learners have the opportunity to notice their vowel production. In doing so, the language learners can visualize how they produce vowels, and also see how their vowel production is similar or different when compared to native pronunciation.

Conclusion

English has become an important language in Chinese education. However, because of the focus on examinations, listening and speaking skills are not considered as important as reading and writing skills. Meanwhile, the lack of research on pronunciation acquisition leaves instructors to their own intuition as to how to go about teaching pronunciation to ESL learners (Derwing & Munro, 2005). A vowel analysis such as in this study, therefore, provides a high degree of awareness of the intelligibility issues that face Mandarin-speaking English learners.

Chapter V. Data of Other Correlates

Chapter Introduction

While collecting the data, the measurements of the other relevant acoustic correlates were also collected. These measurements are listed in this chapter for future research; specifically, F0, F3, duration, and intensity. For each correlate, the measurement of the ten males/females are presented first, and then the measurements of the two subgroups are provided individually. From all the 20 participants, four correlates of each word were collected. Collectively, 880 tokens have been collected (11x20x4).

Vowels' Pitch/F0 Information of Mandarin Speakers

Pitch or F0 is defined as the lowest frequency of any waveform in a speech sound. According to Koffi (2017, p. 84), pitch/F0 is most relevant when measuring suprasegmentals. This includes stressed or unstressed syllables, lexical stress, contrastive stress, sentence stress, tone levels, or intonation patterns. Therefore, the pitch is not an essential correlate in analyzing vowels for intelligibility purposes.

F0 data of ten males.

Table 5.1

F0 Information of Ten Male Participants

F0	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	185	135	139	123	92	151	185	164	157	169	101
male2<1	118	110	113	110	109	136	114	122	155	114	115
male3<1	129	120	118	113	115	121	119	139	122	129	115
male4<1	136	131	137	135	132	133	128	185	157	152	123
male5 <1	153	164	155	163	161	146	150	150	153	154	154
male6>1	134	141	140	118	107	151	133	128	143	132	116
male7>1	117	115	112	100	101	111	115	113	117	107	101
male8>1	123	149	126	125	122	149	139	135	152	160	148
male9>1	181	157	178	179	170	200	195	184	179	181	192
male10>1	133	141	130	128	125	135	119	129	136	150	129
St. Deviation	24	18	20	24	25	24	29	25	18	24	28
Overall mean	141	136	135	129	123	143	140	145	147	145	129
GAE mean	136	135	129	130	127	124	129	129	137	141	130

F0 data of five males whose LOR<1.

Table 5.2

F0 Information of Five Male Participants with LOR<1

F0	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	185	135	139	123	92	151	185	164	157	169	101
male2<1	118	110	113	110	109	136	114	122	155	114	115
male3<1	129	120	118	113	115	121	119	139	122	129	115
male4<1	136	131	137	135	132	133	128	185	157	152	123
male5 <1	153	164	155	163	161	146	150	150	153	154	154
St. Deviation	26	20	17	21	26	12	29	24	15	22	20
Overall mean	144	132	132	129	122	137	139	152	149	144	122
GAE mean	136	135	129	130	127	124	129	129	137	141	130

F0 data of five males whose LOR>1.

Table 5.3

F0 Information of Five Male Participants with LOR>1

F0	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male6>1	134	141	140	118	107	151	133	128	143	132	116
male7>1	117	115	112	100	101	111	115	113	117	107	101
male8>1	123	149	126	125	122	149	139	135	152	160	148
male9>1	181	157	178	179	170	200	195	184	179	181	192
male10>1	133	141	130	128	125	135	119	129	136	150	129
St. Deviation	25	16	25	29	27	33	32	27	23	28	35
Overall mean	138	141	137	130	125	149	140	138	145	146	137
GAE mean	136	135	129	130	127	124	129	129	137	141	130

F0 data of ten females.

Table 5.4

F0 Information of Ten Female Participants

F0	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	211	223	214	192	214	221	217	229	217	209	214
female2<1	259	242	232	219	219	222	225	215	236	223	212
female3<1	247	234	236	222	237	199	240	231	239	242	240
female4<1	258	198	247	211	246	225	204	243	260	250	237
female5<1	233	238	193	185	191	189	175	179	191	170	200
female6>1	281	225	226	228	221	217	207	221	227	239	213
female7>1	262	291	331	284	289	268	295	253	322	311	456
female8>1	226	206	214	217	232	198	202	215	215	216	220
female9>1	237	274	249	229	282	215	247	220	231	241	190
female10>1	258	255	227	217	256	247	188	243	215	186	255
St. Deviation	21	29	37	27	31	24	34	21	36	39	77
Overall mean	247	239	237	220	239	220	220	225	235	229	244
GAE mean	235	232	219	223	210	212	216	217	232	231	221

F0 data of five females whose LOR<1.

Table 5.5

F0 Information of Five Female Participants Whose LOR<1

F0	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	211	223	214	192	214	221	217	229	217	209	214
female2<1	259	242	232	219	219	222	225	215	236	223	212
female3<1	247	234	236	222	237	199	240	231	239	242	240
female4<1	258	198	247	211	246	225	204	243	260	250	237
female5<1	233	238	193	185	191	189	175	179	191	170	200
St. Deviation	20	18	21	16	21	16	25	25	26	32	17
Overall mean	242	227	224	206	221	211	212	219	229	219	221
GAE mean	235	232	219	223	210	212	216	217	232	231	221

F0 data of five females whose LOR>1.

Table 5.6

F0 Information of Five Female Participants Whose LOR>1

F0	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female6>1	281	225	226	228	221	217	207	221	227	239	213
female7>1	262	291	331	284	289	268	295	253	322	311	456
female8>1	226	206	214	217	232	198	202	215	215	216	220
female9>1	237	274	249	229	282	215	247	220	231	241	190
female10>1	258	255	227	217	256	247	188	243	215	186	255
St. Deviation	22	35	47	28	30	28	43	17	45	46	108
Overall mean	253	250	249	235	256	229	228	230	242	239	267
GAE mean	235	232	219	223	210	212	216	217	232	231	221

The acoustic distance of 1Hz is the threshold for F0. The participants' data above shows that except for the males' vowels [ɪ], [ɛ], and [ʌ], all the other vowels produced by Mandarin speakers have the F0 difference greater than 1 Hz compare to GAE. It means that Mandarin speakers produce those vowels differently than GAE speaker in terms of F0.

Vowels' F3 Information of Mandarin Speakers

F3 provides information about the degree of lip positions (Koffi, 2017). A greater F3 value correlates the lack of lip rounding, while the smaller F3 value means the more the lips are being rounded.-This is unnecessary. You should instead highlight the participants who produced front vowels with smaller F3 values. For example, the females fronted their front vowels more than the males. The speakers' back vowels involve less lip rounding.

F3 data of ten males.

Table 5.7

F3 Information of Ten Male Participants

F3	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	3008	2832	2736	2530	2510	2854	2800	2610	3265	3208	2547
male2<1	2548	2616	2588	2489	2543	2732	3063	3149	2809	2707	2581
male3<1	3000	2779	2741	2530	2511	2852	2947	3008	2978	2859	3032
male4<1	2623	2586	2683	2457	2508	3011	2747	3009	3098	2867	2664
male5 <1	2540	2863	2575	2519	2457	2720	2656	2729	2721	2728	2501
male6>1	3122	3086	2845	2554	2444	2609	2308	2493	2850	2583	2054
male7>1	2723	2561	2551	2351	2472	2557	2666	2574	2478	2773	2543
male8>1	3353	2787	2874	2470	2518	2688	2895	3143	2804	2865	2651
male9>1	2917	2823	2883	2666	2601	2456	2630	2894	2649	2608	2774
male10>1	2858	2808	2645	2528	2578	3021	2955	3110	2827	2711	2893
St. Deviation	265	156	125	80	50	186	217	251	224	178	262
Overall mean	2869	2774	2712	2509	2514	2750	2767	2872	2848	2791	2624
GAE mean	3010	2550	2691	2480	2410	2440	2410	2459	2240	2240	2390

F3 data of five males whose LOR<1.

Table 5.8

F3 Information of Five Male Participants with LOR<1

F3	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	3008	2832	2736	2530	2510	2854	2800	2610	3265	3208	2547
male2<1	2548	2616	2588	2489	2543	2732	3063	3149	2809	2707	2581
male3<1	3000	2779	2741	2530	2511	2852	2947	3008	2978	2859	3032
male4<1	2623	2586	2683	2457	2508	3011	2747	3009	3098	2867	2664
male5 <1	2540	2863	2575	2519	2457	2720	2656	2729	2721	2728	2501
St. Deviation	240	127	79	32	31	118	162	223	219	201	214
Overall mean	2744	2735	2665	2505	2506	2834	2843	2901	2974	2874	2665
GAE mean	3010	2550	2691	2480	2410	2440	2410	2459	2240	2240	2390

F3 data of five males whose LOR>1.

Table 5.9

F3 Information of Five Male Participants Whose LOR>1

F3	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male6>1	3122	3086	2845	2554	2444	2609	2308	2493	2850	2583	2054
male7>1	2723	2561	2551	2351	2472	2557	2666	2574	2478	2773	2543
male8>1	3353	2787	2874	2470	2518	2688	2895	3143	2804	2865	2651
male9>1	2917	2823	2883	2666	2601	2456	2630	2894	2649	2608	2774
male10>1	2858	2808	2645	2528	2578	3021	2955	3110	2827	2711	2893
St. Deviation	247	186	152	116	67	215	256	299	157	117	324
Participants' mean	2995	2813	2760	2514	2523	2666	2691	2843	2722	2708	2583
GAE mean	3010	2550	2691	2480	2410	2440	2410	2459	2240	2240	2390

F3 data of ten females.

Table 5.10

F3 Information of Ten Female Participants

F3	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	3558	3015	3181	2940	3240	3167	3181	3134	3023	2961	3223
female2<1	3242	3227	3083	2645	2728	2923	2797	3525	3524	3561	2720
female3<1	3032	3013	2630	2506	2525	2838	2918	2879	2783	2854	2638
female4<1	3291	3122	2933	2571	2604	3180	3192	3040	2930	2804	2944
female5<1	3200	3262	2689	2385	2084	2542	2886	3192	3026	3219	3164
female6>1	3393	2978	2975	2514	2533	2919	2741	3002	2945	2814	2556
female7>1	3093	2186	3045	2801	2792	2919	2831	3018	3102	3065	2814
female8>1	3450	3182	3167	3062	3072	3035	2928	3006	2968	2911	2924
female9>1	3252	3265	2820	2548	2626	2788	2838	2947	2774	2750	2492
female10>1	3181	3069	2697	2900	2827	3125	3411	2974	3301	3246	2857
St. Deviation	161	316	203	224	318	196	216	182	228	256	242
Overall mean	3269	3032	2922	2687	2703	2944	2972	3072	3038	3019	2833
GAE mean	3310	3070	3047	2990	2850	2810	2710	2828	2680	2670	2780

F3 data of five females whose LOR<1.

Table 5.11

F3 Information of Five Male Participants with LOR<1

F3	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	3558	3015	3181	2940	3240	3167	3181	3134	3023	2961	3223
female2<1	3242	3227	3083	2645	2728	2923	2797	3525	3524	3561	2720
female3<1	3032	3013	2630	2506	2525	2838	2918	2879	2783	2854	2638
female4<1	3291	3122	2933	2571	2604	3180	3192	3040	2930	2804	2944
female5<1	3200	3262	2689	2385	2084	2542	2886	3192	3026	3219	3164
St. Deviation	191	116	240	208	416	263	181	239	279	313	260
Overall mean	3265	3128	2903	2609	2636	2930	2995	3154	3057	3080	2938
GAE mean	3310	3070	3047	2990	2850	2810	2710	2828	2680	2670	2780

F3 data of five females whose LOR>1.

Table 5.12

F3 Information of Five Male Participants with LOR>1

F3	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female6>1	3393	2978	2975	2514	2533	2919	2741	3002	2945	2814	2556
female7>1	3093	2186	3045	2801	2792	2919	2831	3018	3102	3065	2814
female8>1	3450	3182	3167	3062	3072	3035	2928	3006	2968	2911	2924
female9>1	3252	3265	2820	2548	2626	2788	2838	2947	2774	2750	2492
female10>1	3181	3069	2697	2900	2827	3125	3411	2974	3301	3246	2857
St. Deviation	148	433	185	233	207	128	266	29	197	200	192
Overall mean	3274	2936	2941	2765	2770	2957	2950	2989	3018	2957	2729
GAE mean	3310	3070	3047	2990	2850	2810	2710	2828	2680	2670	2780

The acoustic distance of 400 Hz is used as the threshold for F3. Based on the information above, the F3 differences between the vowels produced by female participants and GAE are all smaller than 400 Hz. It means that the female Mandarin speakers produce those vowels similar to GAE in regard to lips rounding. However, there are three vowels ([o], [u], and [ʊ]) produced by male participants which have the difference greater than 400 Hz compared to GAE. So, when the male Mandarin speakers produce these vowels, their lips are less rounded than GAE.

Vowels' Duration Information of Mandarin Speakers

Duration is the other vocalic feature of vowel. It deals with whether the vowel is pronounced short or long. In other words, it is the length of time that a sound has been produced. According to Koffi (2017), duration information is very important in accessing foreign-accented English because the length of vowels changed depending on whether they are immediately followed by voiced consonants or voiceless consonants. Therefore, it is not significantly relevant to vowel intelligibility.

Duration data of ten males.

Table 5.13

Duration Information of Ten Male Participants

Duration	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	262	179	195	195	144	214	240	239	239	234	172
male2<1	235	149	184	130	138	188	181	156	195	144	120
male3<1	292	221	270	201	238	256	256	223	181	164	218
male4<1	142	119	137	130	128	143	180	153	136	171	146
male5 <1	202	160	230	223	154	244	240	272	257	248	149
male6>1	169	81	157	125	113	99	154	131	109	109	91
male7>1	208	144	179	191	167	123	189	172	169	190	178
male8>1	203	84	166	164	108	116	163	161	123	200	111
male9>1	164	160	166	171	164	174	248	153	162	148	144
male10>1	215	140	186	209	169	178	225	200	229	131	157
St. Deviation	45	42	38	36	37	54	38	46	50	44	36
Overall mean	209	144	187	174	152	174	208	186	180	174	149
GAE mean	243	192	267	189	278	267	283	265	192	237	188

Duration data of five males whose LOR<1.

Table 5.14

Duration Information of Five Male Participants Whose LOR<1

Duration	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	262	179	195	195	144	214	240	239	239	234	172
male2<1	235	149	184	130	138	188	181	156	195	144	120
male3<1	292	221	270	201	238	256	256	223	181	164	218
male4<1	142	119	137	130	128	143	180	153	136	171	146
male5 <1	202	160	230	223	154	244	240	272	257	248	149
St. Deviation	58	38	50	43	44	45	36	52	48	46	37
Overall mean	227	166	203	176	160	209	219	209	202	192	161
GAE mean	243	192	267	189	278	267	283	265	192	237	188

Duration data of five males whose LOR>1.

Table 5.15

Duration Information of Five Male Participants with LOR>1

Duration	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male6>1	169	81	157	125	113	99	154	131	109	109	91
male7>1	208	144	179	191	167	123	189	172	169	190	178
male8>1	203	84	166	164	108	116	163	161	123	200	111
male9>1	164	160	166	171	164	174	248	153	162	148	144
male10>1	215	140	186	209	169	178	225	200	229	131	157
St. Deviation	24	37	12	32	31	36	40	25	47	39	35
Overall mean	192	122	171	172	144	138	196	163	158	156	136
GAE mean	243	192	267	189	278	267	283	265	192	237	188

Duration data of ten females.

Table 5.16

Duration Information of Ten Female Participants

Duration	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	189	147	146	177	148	141	146	156	151	112	119
female2<1	243	191	229	240	186	206	207	218	173	190	175
female3<1	180	103	132	155	163	173	197	160	124	119	164
female4<1	333	185	339	260	221	230	305	315	255	258	204
female5<1	316	424	430	553	344	419	448	460	319	486	512
female6>1	254	200	212	183	195	158	221	185	183	177	156
female7>1	248	162	175	168	143	179	158	150	142	131	110
female8>1	261	231	226	284	209	159	232	215	228	196	206
female9>1	271	217	120	212	220	224	362	255	254	241	162
female10>1	216	167	154	149	183	158	158	164	107	84	124
St. Deviation	49	86	99	120	57	81	99	97	68	115	117
Overall mean	251	203	216	238	201	205	243	228	194	199	193
GAE mean	306	237	320	254	332	323	353	326	249	303	226

Duration data of five females whose LOR<1.

Table 5.17

Duration Information of Five Female Participants with LOR<1

Duration	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	189	147	146	177	148	141	146	156	151	112	119
female2<1	243	191	229	240	186	206	207	218	173	190	175
female3<1	180	103	132	155	163	173	197	160	124	119	164
female4<1	333	185	339	260	221	230	305	315	255	258	204
female5<1	316	424	430	553	344	419	448	460	319	486	512
St. Deviation	71	125	128	160	79	109	120	128	81	153	158
Overall mean	252	210	255	277	212	234	261	262	204	233	235
GAE mean	306	237	320	254	332	323	353	326	249	303	226

Duration data of five females whose LOR>1.

Table 5.18

Duration Information of Five Female Participants with LOR>1

Duration	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female6>1	254	200	212	183	195	158	221	185	183	177	156
female7>1	248	162	175	168	143	179	158	150	142	131	110
female8>1	261	231	226	284	209	159	232	215	228	196	206
female9>1	271	217	120	212	220	224	362	255	254	241	162
female10>1	216	167	154	149	183	158	158	164	107	84	124
St. Deviation	21	30	43	53	30	29	83	42	60	60	37
Overall mean	250	195	177	199	190	176	226	194	183	166	152
GAE mean	306	237	320	254	332	323	353	326	249	303	226

It is generally believed that if the duration distance between two segments is ≤10 ms, the ear could not perceive any length difference between them. According to the duration information above. The duration difference between Mandarin-accented vowels and GAE vowels are greater than 10 ms. It indicates that the Mandarin speakers produce the vowels shorter than GAE. Besides, the duration of all vowels produced by both male and female Mandarin speakers are smaller than the same vowel's duration of GAE. That is, when Mandarin speakers produce the English vowels, they produce them shorter than GAE speakers do.

Vowels' Intensity Information of Mandarin Speakers

The intensity of speech segment is directly related to the degree of constriction that occurs inside the mouth when that sound is being produced (Koffi, 2017, p. 88). Intensity is particularly useful in the analysis of fricatives and syllable structure instead of vowel intelligibility analysis.

Intensity data of ten males

Table 5.19

Intensity Information of Ten Male Participants

Intensity	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	51	50	51	48	47	51	46	47	51	51	49
male2<1	53	51	52	52	52	54	55	53	52	52	53
male3<1	53	54	52	52	52	45	44	51	54	56	47
male4<1	56	55	55	56	55	57	58	56	56	57	54
male5 <1	68	79	70	71	68	66	67	67	67	67	68
male6>1	55	55	57	56	57	54	53	54	55	53	51
male7>1	57	53	55	58	56	52	57	55	56	54	55
male8>1	60	68	67	69	69	70	69	69	66	65	68
male9>1	58	55	59	59	56	60	61	60	54	57	62
male10>1	57	57	55	57	56	58	63	59	60	60	60
St. Deviation	5	9	6	7	7	7	8	7	6	5	7
Overall mean	57	58	57	58	57	57	57	57	57	57	57

Intensity data of five males whose LOR<1.

Table 5.20

Intensity Information of Five Male Participants with LOR<1

Intensity	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male1<1	51	50	51	48	47	51	46	47	51	51	49
male2<1	53	51	52	52	52	54	55	53	52	52	53
male3<1	53	54	52	52	52	45	44	51	54	56	47
male4<1	56	55	55	56	55	57	58	56	56	57	54
male5 <1	68	79	70	71	68	66	67	67	67	67	68
St. Deviation	7	12	8	9	8	8	9	8	6	6	8
Overall mean	56	58	56	56	55	55	54	55	56	57	54

Intensity data of five males whose LOR>1.

Table 5.21

Intensity Information of Five Male Participants Whose LOR>1

Intensity	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
male6>1	55	55	57	56	57	54	53	54	55	53	51
male7>1	57	53	55	58	56	52	57	55	56	54	55
male8>1	60	68	67	69	69	70	69	69	66	65	68
male9>1	58	55	59	59	56	60	61	60	54	57	62
male10>1	57	57	55	57	56	58	63	59	60	60	60
St. Deviation	2	6	5	5	6	7	6	6	5	5	7
Overall mean	57	58	59	60	59	59	61	59	58	58	59

Intensity data of ten females.

Table 5.22

Intensity Information of Ten Female Participants

Intensity	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	57	60	60	56	59	59	60	60	60	58	59
female2<1	56	57	57	58	57	59	56	55	56	56	54
female3<1	57	57	55	52	52	53	54	55	56	54	49
female4<1	56	53	53	55	54	56	51	55	55	56	50
female5<1	53	53	53	55	57	60	63	57	55	56	55
female6>1	56	53	54	49	49	52	52	50	56	56	49
female7>1	57	57	62	63	63	58	62	60	56	55	57
female8>1	57	56	57	58	58	59	61	61	63	62	61
female9>1	52	51	53	50	51	47	51	47	45	49	45
female10>1	56	56	58	55	53	53	53	51	54	53	56
St. Deviation	2	3	3	4	4	4	5	5	5	3	5
Overall mean	56	55	56	55	55	56	56	55	56	56	54

Intensity data of five females whose LOR<1.

Table 5.23

Intensity Information of Five Female Participants with LOR<1

Intensity	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female1<1	57	60	60	56	59	59	60	60	60	58	59
female2<1	56	57	57	58	57	59	56	55	56	56	54
female3<1	57	57	55	52	52	53	54	55	56	54	49
female4<1	56	53	53	55	54	56	51	55	55	56	50
female5<1	53	53	53	55	57	60	63	57	55	56	55
St. Deviation	2	3	3	2	3	3	5	2	2	1	4
Overall mean	56	56	56	55	56	57	57	56	56	56	53

Intensity data of five females whose LOR>1.

Table 5.24

Intensity Information of Five Female Participants Whose LOR>1

Intensity	heed	hid	hayed	head	had	hod	hawed	hoed	hood	who'd	hud
female6>1	56	53	54	49	49	52	52	50	56	56	49
female7>1	57	57	62	63	63	58	62	60	56	55	57
female8>1	57	56	57	58	58	59	61	61	63	62	61
female9>1	52	51	53	50	51	47	51	47	45	49	45
female10>1	56	56	58	55	53	53	53	51	54	53	56
St. Deviation	2	3	4	6	6	5	5	6	6	5	6
Overall mean	56	55	57	55	55	54	56	54	55	55	54

According to Hansen (2001), the acoustic distance of 3 dB is the just perceptible difference. That is, if the intensity distance between two segments is less than 3 dB, the human ears cannot perceive any difference between them. From the information above, the males' vowel intensity values are all between 54 Hz and 56 Hz. The females' vowel intensity values are either 57 Hz or 58 Hz. Consequently, there is no significant difference between the vowel intensity produced by the Mandarin speakers.

Summary

As it has been analyzed throughout this chapter, each speech sound can be described and analyzed by using the acoustic correlates: pitch/F0, formant frequency, intensity, and duration. Meanwhile, each acoustic correlate relates to specific perception of a segment or classes of segments. The thresholds: 1Hz for Pitch/F0, 400Hz for F3, 10ms for duration, and 3dB for intensity are used for these correlates. Even though these correlates are not directly relevant to vowel intelligibility, the data can still be used for further research. To be specific, the data of pitch/ F0 can be used for studies related to stress/tone; F3 data for studies about how Mandarin speakers produce /j/ and /w/; and duration and intensity data for the supreasegmentals studies.

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Appendix A: Relative Functional Load of Vowels

N0	Vowels	Percentages
1	bit/bat	100
2	beet/bit	95
3	bought/boat	88
4	bit/but	85
5	bit/bait	80
6	cat/cot	76
7	cat/cut	68
8	cot/cut	65
9	caught/curt	64
10	coat/curt	63
11	bit/bet	54
12	bet/bait	53
13	bet/bat	53
14	coat/coot	51
15	cat/cart	51
16	beet/boot	50
17	bet/but	50
18	bought/boot	50
19	hit/hurt	49
20	beat/beard	47
21	pet/pot	45
22	hard/hide	44
23	bet/bite	43
24	cart/caught	43
25	cart/cur	41
26	boat/bout	40.5
27	cut/curt	40
28	cut/cart	38
29	Kay/care	35
30	cart/cot	31.5
31	*here/hair6	30
32	light/lout	30
33	*cot/caught	26
34	fire/fair	25
35	her/here	24
36	buy/boy	24
37	car/cow	23
38	her/hair	21
39	*tire/tower	19
40	box/books	18
41	*paw/pore	15
42	pill/pull	13.5

43	pull/pole	12
44	bid/beard	11
45	bad/beard	10
46	*pin/pen	9
47	*put/putt	9
48	bad/Baird	8
49	*pull/pool	7
50	*sure/shore	5
51	pooh/poor	5
52	*cam/calm	4.5
53	purr/poor	4.5
54	good/gourd	1

Appendix B: RFL and Intelligibility Level Threshold

N0	**F1 Distance**	**Masking Levels**	**RFL**	**Intelligibility Rating**
1.	> 60 Hz	No masking	0-24%	Good intelligibility
2.	41 Hz – 60 Hz	Slight masking	25-49%	Above Average intelligibility
3.	21 Hz – 40 Hz	Moderate masking	50-74%	Questionable intelligibility
4.	0 Hz – 20 Hz	Complete masking	75-100%	Poor intelligibility

Appendix C: F1 and F2's Data of Each Vowel Repetition Produced by Male Participants

		F1 (Hz)						F2 (Hz)					
Speakers	Vowels	V1	V2	V3	Mean	Range	Difference	V1	V2	V3	Mean	Range	Difference
	[i]	307	319	318	315	307-319	12	2217	2188	2252	2219	2188-2252	64
	[ɪ]	341	335	366	347	335-366	31	2036	2136	2252	2141	2036-2252	216
	[e]	331	341	365	346	331-365	34	2133	1982	2106	2074	1982-2133	151
	[ɛ]	705	681	679	688	679-705	26	1724	1747	1755	1742	1724-1755	31
	[æ]	776	723	750	750	723-776	53	1652	1635	1632	1640	1632-1652	20
1M	[ɑ]	333	329	337	333	329-337	8	1136	1479	1786	1467	1136-1786	650
	[ɔ]	556	577	607	580	556-607	51	896	997	955	949	896-997	101
	[o]	384	427	447	419	384-447	63	909	1030	1160	1033	909-1160	251
	[ʊ]	316	329	328	324	316-329	13	1910	2119	2175	2068	1910-2175	251
	[u]	307	322	335	321	307-335	28	1736	1948	1809	1831	1736-1948	212
	[ʌ]	777	771	783	777	771-783	12	1278	1282	1287	1282	1278-1287	9
	[i]	280	283	314	292	280-314	34	2560	2435	2388	2461	2388-2560	172
	[ɪ]	309	306	312	309	306-312	6	2353	2318	2312	2328	2312-2353	41
	[e]	309	302	309	307	302-309	7	2366	2295	2247	2303	2247-2295	48
	[ɛ]	640	624	575	613	575-640	65	1855	1822	1846	1841	1822-1855	33
	[æ]	601	625	563	596	563-601	38	1886	1818	1768	1824	1768-1886	118
2M	[ɑ]	521	622	570	571	521-611	90	1200	1167	1271	1213	1167-1271	104
	[ɔ]	427	577	562	522	427-577	150	910	977	970	952	910-977	67
	[o]	286	298	282	289	282-298	16	1370	1349	966	1228	966-1370	404
	[ʊ]	293	313	288	298	288-313	25	1227	1993	975	1398	975-1993	1018
	[u]	290	291	292	291	290-292	2	783	878	860	840	783-878	95
	[ʌ]	766	744	763	758	744-766	22	1327	1242	1224	1264	1224-1327	103
	[i]	613	635	642	630	613-642	29	1852	1768	1764	1795	1764-1852	88
	[ɪ]	758	632	788	726	632-788	156	1627	1765	1592	1661	1592-1765	173
	[e]	378	448	445	424	378-448	70	2250	2137	2126	2171	2126-2250	124
	[ɛ]	780	721	784	762	721-784	70	1633	1687	1648	1656	1633-1687	54
	[æ]	736	708	745	730	708-745	37	1731	1806	1729	1755	1729-1806	77
3M	[ɑ]	537	569	544	550	537-569	32	1524	1197	1373	1365	1197-1524	327
	[ɔ]	810	842	764	805	764-842	78	1147	1261	1148	1185	1147-1261	114
	[o]	526	470	423	473	423-526	103	2284	1068	1078	1477	1068-2284	1216
	[ʊ]	327	309	344	327	309-344	35	1182	854	1203	1080	854-1203	349
	[u]	339	329	345	338	329-345	16	971	879	981	944	879-981	102
	[ʌ]	786	840	831	819	786-840	54	1140	1101	1026	1089	1026-1140	114
	[i]	324	335	345	335	324-345	21	2247	2205	2170	2207	2170-2247	77
	[ɪ]	399	375	379	384	375-399	24	2139	2117	2069	2108	2069-2139	70
	[e]	405	363	371	380	363-405	42	2105	2156	2194	2152	2105-2194	89
	[ɛ]	645	674	691	670	645-691	46	1646	1658	1628	1644	1628-1658	89
	[æ]	617	635	670	641	617-670	53	1541	1537	1505	1528	1505-1541	36
4M	[ɑ]	387	368	366	374	366-387	21	817	794	805	805	794-817	23
	[ɔ]	643	628	618	630	618-643	25	978	988	951	972	951-988	37
	[o]	559	629	603	597	559-629	70	911	957	952	940	911-957	46
	[ʊ]	437	390	390	406	390-437	47	848	843	809	833	809-848	39
	[u]	382	381	389	384	381-389	8	732	813	747	764	732-813	81
	[ʌ]	780	788	802	790	780-802	22	1138	1254	1199	1197	1138-1254	116
	[i]	481	487	468	479	481-487	6	2169	2116	2086	2124	2086-2169	83
	[ɪ]	490	488	504	494	488-504	16	2193	2207	2090	2163	2090-2207	117
	[e]	732	762	757	750	732-762	30	1785	1736	1784	1768	1736-1785	49
5M	[ɛ]	767	734	699	733	699-767	68	1829	1748	1777	1785	1748-1829	49
	[æ]	745	772	752	756	745-772	27	1829	1753	1724	1769	1724-1829	105
	[ɑ]	724	710	713	716	710-724	14	1369	1180	1180	1243	1180-1369	189
	[ɔ]	729	745	782	752	729-782	53	1225	1153	1152	1177	1152-1225	73
	[o]	549	583	593	575	549-593	44	1212	1093	1229	1178	1093-1229	136

	[ʊ]	465	476	470	470	465-476	11	1070	1077	1141	1096	1070-1141	136
	[u]	467	453	443	454	443-467	24	988	1042	1123	1051	988-1123	135
	[ʌ]	934	916	1007	952	916-1007	91	1385	1435	1420	1413	1385-1435	50
	[i]	349	304	273	309	273-349	76	2169	2358	2327	2285	2169-2358	189
	[ɪ]	299	290	298	296	290-298	8	2311	2310	2294	2305	2294-2311	17
	[e]	420	380	424	408	380-424	44	2243	2268	2201	2237	2201-2268	67
	[ɛ]	712	711	728	717	711-728	17	1977	1973	1941	1964	1941-1977	36
	[æ]	820	766	766	784	766-820	54	1822	1884	1812	1839	1812-1884	72
6M	[ɑ]	710	752	679	714	679-752	73	939	1155	1150	1081	939-1155	216
	[ɔ]	747	756	836	780	747-836	89	1238	1301	1349	1296	1238-1349	111
	[o]	495	473	536	501	473-536	89	1141	1018	1044	1068	1018-1141	123
	[ʊ]	514	408	396	439	369-514	145	1596	1509	1175	1427	1175-1596	421
	[u]	303	297	331	310	297-331	34	1130	1058	1110	1099	1058-1130	72
	[ʌ]	874	807	762	814	762-874	112	1421	1430	1392	1414	1392-1430	38
	[i]	301	312	309	307	301-312	11	2097	2212	2100	2136	2097-2212	115
	[ɪ]	343	350	333	342	333-350	17	2043	2053	2037	2044	2037-2053	16
	[e]	406	382	392	393	382-406	24	2016	2030	2027	2024	2016-2030	14
	[ɛ]	731	731	743	735	731-743	12	1721	1668	1674	1688	1668-1721	53
	[æ]	762	761	748	757	748-762	14	1628	1697	1651	1659	1628-1697	69
7M	[ɑ]	419	435	414	423	414-435	21	931	883	887	900	883-931	48
	[ɔ]	597	610	610	606	597-610	13	946	925	951	941	946-951	5
	[o]	397	424	428	416	397-428	31	931	918	909	919	909-931	22
	[ʊ]	315	310	340	322	310-340	30	882	862	907	884	862-907	45
	[u]	334	358	353	348	334-358	24	995	1151	893	1013	893-1151	258
	[ʌ]	771	770	770	770	770-771	24	1401	1367	1365	1378	1365-1401	36
	[i]	277	280	298	285	277-298	21	2434	2407	2416	2419	2407-2434	27
	[ɪ]	440	690	431	520	431-690	259	2132	2183	2138	2151	2132-2183	51
	[e]	407	400	551	453	400-551	151	2330	2337	2320	2329	2320-2337	51
	[ɛ]	930	920	931	927	920-931	151	1748	1694	1669	1704	1694-1748	54
	[æ]	923	887	912	907	887-923	36	1765	1670	1726	1720	1670-1765	95
8M	[ɑ]	834	832	912	859	832-912	80	1216	1275	1397	1296	1216-1397	181
	[ɔ]	652	666	726	681	652-726	74	867	994	1189	1017	867-1189	181
	[o]	598	743	540	627	540-743	74	2004	2544	972	1840	972-2544	181
	[ʊ]	404	373	470	416	373-470	97	974	1025	1816	1272	974-1816	842
	[u]	351	337	369	352	351-369	97	1115	855	1230	1067	855-1230	375
	[ʌ]	836	831	868	845	831-868	37	1300	1356	1343	1333	1300-1356	56
	[i]	343	339	328	337	328-343	15	2515	2531	2558	2535	2515-2558	43
	[ɪ]	384	385	358	376	358-385	27	2397	2339	2415	2384	2339-2415	76
	[e]	450	372	416	413	372-450	78	2401	2404	2394	2400	2394-2404	10
	[ɛ]	685	638	691	671	638-691	53	2024	2018	2006	2016	2006-2024	18
	[æ]	658	735	704	699	658-735	77	1907	1902	1874	1894	1874-1907	33
9M	[ɑ]	862	768	787	806	768-862	94	1492	1500	1511	1501	1492-1511	19
	[ɔ]	655	700	734	696	655-734	79	1057	1124	1607	1263	1057-1607	550
	[o]	684	516	507	569	507-684	177	1705	1206	1098	1336	1098-1705	607
	[ʊ]	357	395	326	359	326-395	69	1097	1417	1329	1281	1097-1417	320
	[u]	318	332	353	334	318-353	35	831	947	1057	945	831-1057	226
	[ʌ]	380	381	362	374	362-381	19	1113	1061	1149	1108	1061-1149	88
	[i]	327	336	323	329	323-336	13	2152	2138	2167	2152	2138-2167	29
	[ɪ]	348	328	330	335	328-348	20	2080	2125	2143	2116	2080-2143	63
	[e]	397	380	385	387	380-397	17	2008	2001	2027	2012	2001-2027	26
	[ɛ]	765	719	677	720	677-765	88	1645	1669	1681	1665	1645-1681	36
	[æ]	715	689	674	693	674-715	41	1660	1686	1680	1675	1660-1686	26
10M	[ɑ]	466	429	468	454	429-468	39	897	904	946	916	897-946	49
	[ɔ]	733	663	683	693	663-733	70	1002	1009	1030	1014	1002-1030	28
	[o]	482	407	582	490	407-582	175	1362	1075	1715	1384	1075-1715	640
	[ʊ]	465	389	384	413	384-465	81	1671	1034	1013	1239	1013-1671	658
	[u]	405	384	385	391	384-405	21	1187	1016	1042	1082	1016-1187	171
	[ʌ]	826	724	793	781	724-826	102	1278	1181	1197	1219	1181-1278	97

Appendix D: F1 and F2's Data of Each Vowel Repetition Produced by Female Participants

		F1 (Hz)						F2 (Hz)					
Speakers	Vowels	V1	V2	V3	Mean	Range	Difference	V1	V2	V3	Mean	Range	Difference
	[i]	386	401	365	384	365-401	36	2713	2589	2659	2654	2589-2713	124
	[ɪ]	433	453	435	440	433-453	20	2275	2322	2379	2325	2275-2379	104
	[e]	426	494	444	455	426-494	68	2412	2397	2375	2395	2375-2412	37
	[ɛ]	788	854	804	815	788-854	66	1907	2019	1991	1972	1991-2019	28
	[æ]	868	859	860	862	859-868	9	1529	1559	1532	1540	1529-1559	30
1F	[ɑ]	729	660	688	692	660-729	69	1169	1155	1172	1165	1155-1172	17
	[ɔ]	733	694	788	738	694-788	94	1164	1171	1138	1158	1138-1171	33
	[o]	503	479	542	508	479-542	63	1116	1077	1203	1132	1077-1203	126
	[ʊ]	408	408	426	414	408-426	18	1168	1079	989	1079	989-1168	179
	[u]	418	421	399	413	399-421	22	1087	1146	914	1049	914-1146	232
	[ʌ]	930	904	851	895	851-930	79	1680	1641	1585	1635	1585-1680	95
	[i]	363	376	390	376	363-390	27	2450	2381	2407	2413	2381-2450	69
	[ɪ]	350	401	378	376	350-401	51	2453	2373	2397	2408	2373-2453	80
	[e]	376	799	429	535	376-799	423	2390	2339	2273	2334	2273-2390	117
	[ɛ]	946	931	944	940	931-946	15	2016	1950	1941	1969	1941-2016	75
	[æ]	958	909	968	945	909-968	59	1963	1969	1988	1973	1963-1988	25
2F	[ɑ]	951	931	915	932	915-951	36	1573	1485	1559	1539	1485-1573	88
	[ɔ]	924	928	917	923	917-928	11	1550	1515	1556	1540	1515-1556	41
	[o]	444	439	436	440	436-444	8	1028	1008	1032	1023	1008-1032	41
	[ʊ]	414	431	420	422	414-431	17	954	939	883	925	883-939	56
	[u]	432	419	429	427	419-432	13	891	1129	915	978	891-1129	238
	[ʌ]	995	884	963	947	884-995	111	1656	1627	1632	1638	1627-1656	29
	[i]	330	323	354	336	323-354	31	2405	2419	2544	2456	2405-2544	139
	[ɪ]	335	348	315	333	315-348	33	2542	2446	2321	2436	2321-2542	221
	[e]	357	340	380	359	340-380	33	2388	2271	2314	2324	2271-2388	117
	[ɛ]	571	658	564	598	564-658	94	1869	1863	1789	1840	1789-1869	80
	[æ]	546	507	514	522	507-546	39	1935	1651	1793	1793	1651-1935	284
3F	[ɑ]	592	459	517	523	459-592	133	1233	1093	1058	1128	1058-1233	175
	[ɔ]	850	615	655	707	615-850	235	1399	1372	1227	1333	1227-1399	172
	[o]	410	416	452	426	410-452	42	1144	958	1038	1047	958-1144	172
	[ʊ]	407	381	372	387	372-407	35	833	1057	896	929	833-1057	224
	[u]	397	326	367	363	326-397	71	1335	787	764	962	787-1335	548
	[ʌ]	599	570	606	592	570-606	36	1724	1727	1681	1711	1681-1727	46
	[i]	334	358	365	352	334-365	31	2682	2599	2672	2651	2599-2682	83
	[ɪ]	413	414	375	401	375-414	39	2591	2642	2486	2573	2486-2591	83
	[e]	460	418	425	434	418-460	42	2481	2488	2437	2469	2437-2488	51
	[ɛ]	643	669	669	660	643-669	26	2154	2033	2194	2127	2033-2194	161
	[æ]	730	719	852	767	719-852	133	1734	1780	1746	1753	1734-1780	46
4F	[ɑ]	427	449	424	433	424-449	25	1238	1124	1088	1150	1099-1238	139
	[ɔ]	589	640	671	633	589-671	82	1112	1092	1157	1120	1092-1157	65
	[o]	462	476	493	477	462-493	31	1459	1199	1265	1308	1199-1459	260
	[ʊ]	395	397	403	398	395-403	8	755	963	1098	939	755-1098	343
	[u]	420	399	391	403	399-420	21	774	825	958	852	774-958	184
	[ʌ]	847	878	911	879	847-911	64	1531	1529	1585	1548	1529-1585	56
	[i]	448	429	394	424	394-448	54	2682	2488	2409	2526	2409-2682	273
	[ɪ]	447	444	420	437	420-447	27	2231	2554	2883	2556	2231-2883	652
	[e]	670	574	553	599	553-670	117	2118	1896	1669	1894	1669-2118	449
	[ɛ]	830	845	881	852	830-881	51	1634	1604	1842	1693	1604-1842	238
5F	[æ]	937	945	978	953	937-978	41	1736	1688	1399	1608	1399-1736	337
	[ɑ]	939	931	944	938	931-944	13	1376	1381	1371	1376	1371-1381	337
	[ɔ]	974	1003	978	985	974-1003	29	1456	1384	1393	1411	1384-1456	72
	[o]	780	854	846	827	780-854	74	1192	1194	1188	1191	1188-1194	6
	[ʊ]	530	550	483	521	483-550	67	1120	1087	1132	1113	1087-1132	45

	[u]	572	594	626	597	572-626	54	1091	1164	1127	1127	1091-1164	45
	[ʌ]	844	844	902	863	844-902	58	1275	1243	1305	1274	1243-1305	62
6F	[i]	331	346	382	353	331-382	51	2743	2764	2797	2768	2743-2797	54
	[ɪ]	465	477	448	463	448-477	29	2598	2498	2593	2563	2498-2598	100
	[e]	488	468	475	477	468-488	20	2497	2470	2484	2484	2470-2497	27
	[ɛ]	827	814	814	818	814-827	13	1503	1953	2126	1861	1503-2126	623
	[æ]	774	794	828	799	774-828	54	1537	2177	1994	1903	1537-2177	623
	[ɑ]	803	785	792	793	785-803	18	1157	1198	1211	1189	1157-1211	54
	[ɔ]	826	854	769	816	769-854	85	1086	1231	1277	1198	1086-1277	191
	[o]	641	555	612	603	555-641	86	959	940	941	947	940-959	19
	[ʊ]	419	415	428	421	415-428	13	842	827	642	770	642-842	200
	[u]	417	439	428	428	417-439	22	787	775	735	766	735-787	52
	[ʌ]	814	926	941	894	814-941	127	1494	1481	1468	1481	1468-1494	26
7F	[i]	373	364	382	373	364-382	18	2528	2472	2486	2495	2472-2528	56
	[ɪ]	369	381	367	372	367-381	14	2514	2435	2490	2480	2435-2514	79
	[e]	477	479	481	479	477-481	4	2461	2392	2392	2415	2393-2461	68
	[ɛ]	819	789	803	804	789-819	30	1964	1939	1923	1942	1923-1964	41
	[æ]	851	869	828	849	828-869	41	1893	1848	1855	1865	1848-1893	45
	[ɑ]	771	782	796	783	771-796	25	1170	1216	1245	1210	1170-1245	75
	[ɔ]	889	901	868	886	868-901	33	1312	1396	1440	1383	1312-1440	128
	[o]	495	498	516	503	495-516	21	975	973	926	958	926-975	49
	[ʊ]	413	425	438	425	413-438	25	840	858	888	862	858-888	49
	[u]	417	425	416	419	416-425	9	865	874	868	869	865-874	49
	[ʌ]	887	881	878	882	878-887	9	1466	1442	1491	1466	1442-1491	49
8F	[i]	418	406	399	408	399-418	19	2769	2807	2856	2811	2769-2856	49
	[ɪ]	976	817	898	897	817-976	159	2261	2287	2241	2263	2241-2287	46
	[e]	440	500	451	464	440-500	60	2687	2624	2671	2661	2624-2687	63
	[ɛ]	998	1030	978	1002	978-1030	52	2116	2165	2025	2102	2025-2165	140
	[æ]	971	934	989	965	934-989	52	2290	2213	2184	2229	2184-2290	106
	[ɑ]	446	519	507	491	446-519	73	1139	1171	1169	1160	1139-1171	32
	[ɔ]	778	781	792	784	778-792	14	1380	1311	1307	1333	1307-1380	73
	[o]	495	560	527	527	495-560	65	1096	1165	1130	1130	1096-1165	73
	[ʊ]	492	552	573	539	492-573	81	1001	1099	1149	1083	1001-1149	73
	[u]	436	458	456	450	436-458	22	1082	1037	1012	1044	1012-1082	70
	[ʌ]	1049	979	962	997	963-1049	86	1825	1763	1761	1783	1761-1825	64
9F	[i]	306	307	303	305	303-307	4	2492	2526	2527	2515	2492-2527	35
	[ɪ]	327	335	348	337	327-348	21	2548	2484	2416	2483	2416-2548	132
	[e]	469	433	452	451	433-469	36	2418	2457	2354	2410	2354-2457	103
	[ɛ]	837	875	887	866	837-887	50	1958	1962	1963	1961	1958-1963	5
	[æ]	884	786	906	859	786-906	120	1861	1871	1981	1904	1861-1981	120
	[ɑ]	714	818	800	777	714-818	104	1223	1206	1260	1230	1206-1223	17
	[ɔ]	752	840	773	788	752-840	88	1128	1250	1099	1159	1099-1250	151
	[o]	511	610	579	567	511-610	99	988	1044	1100	1044	988-1199	151
	[ʊ]	374	339	416	376	339-416	77	874	922	831	876	831-922	91
	[u]	341	310	355	335	310-355	45	867	869	777	838	777-869	92
	[ʌ]	968	1127	1051	1049	968-1127	159	1741	1725	1637	1701	1637-1741	92
10F	[i]	395	366	400	387	366-400	34	2833	2825	2744	2801	2744-2833	89
	[ɪ]	403	466	456	442	403-456	53	2662	2601	2628	2630	2601-2662	61
	[e]	519	518	515	517	515-519	4	2547	2539	2489	2525	2489-2547	58
	[ɛ]	807	728	773	769	728-807	4	2205	2129	2105	2146	2105-2205	100
	[æ]	766	832	785	794	766-832	66	1936	1963	1939	1946	1936-1963	27
	[ɑ]	568	601	645	605	568-645	77	1139	1211	1265	1205	1139-1265	126
	[ɔ]	814	795	772	794	772-814	42	1255	1388	1361	1335	1255-1388	133
	[o]	530	518	536	528	518-536	18	1125	1099	1135	1120	1099-1135	36
	[ʊ]	457	452	485	465	452-482	30	940	1393	1598	1310	940-1598	658
	[u]	463	493	508	488	463-508	45	1600	1459	1345	1468	1345-1600	255
	[ʌ]	873	840	877	863	840-877	37	1616	1728	1641	1662	1616-1728	112

Appendix E: IRB Approval

ST. CLOUD STATE UNIVERSITY
EDUCATION FOR LIFE

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

Name: Liping Ma

Email: lma@stcloudstate.edu

IRB PROTOCOL DETERMINATION: Expedited Review-1

Co-Investigator Ettien Koffi

Project Title: Investigating how the social networks of non-native language learns influence their vowel intelligibility

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Please note the following important information concerning IRB projects:

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Benjamin Witts
Associate Professor- Applied Behavior Analysis
Department of Community Psychology,Counseling, and Family Therapy

IRB Institutional Official:

Dr. Latha Ramakrishnan
Interim Associate Provost for Research
Dean of Graduate Studies

OFFICE USE ONLY

SCSU IRB# 1786 - 2263	**Type:** Expedited Review-1	**Today's Date:** 3/20/2018
1st Year Approval Date: 3/19/2018	**2nd Year Approval Date:**	**3rd Year Approval Date:**
1st Year Expiration Date: 3/18/2019	**2nd Year Expiration Date:**	**3rd Year Expiration Date:**

Appendix F: Consent Form

Investigating How the Social Networks of Non-Native Language Learners Influence Their Vowel Intelligibility

Consent to Participate

You are invited to participate in a research study about the correlation between social network analysis and its impact English proficiency. Sociolinguists believe that the types of social network a person is in influences their proficiency level in a second language. I want to test to see if this hypothesis is true for non-native speakers of English at St. Cloud State University. I want to investigate whether or not the social network you are in has any impact on your continued proficiency in English.

Involvement in the study is voluntary, you may choose to participate or not. If you are interested in my topic, and want to know the relationship between social networks and pronunciation, you can participate in this study.

The benefits of this research are that it can help you determine whether or not you are maximizing your social interactions to benefit your speech repertoire in English. By participating in this study, you will know the strength and weaknesses of your social network and understand its potential impact on your oral proficiency in English, especially the vowel pronunciation intelligibility. It will empower you to make decisions that have optimal benefits for your English proficiency.

Risks and discomforts: There are no known risks or discomfort in participating in this study. If there are any risks at all, they are not higher than the risks and discomforts associated with answering questions from somebody you have not met before.

Data collected will remain confidential. The answers you provide will be coded and all the answers will be tabulated. As a result, nobody can look at the aggregated data and determine who the participant is. Your name will not be disclosed nor will you be identified by direct quotes.

This study also involves the audio recording. Neither your name nor any other identifying information will be associated with the audio or audio recording or the transcript. Only the research team will be able to listen to the recordings.

Participating in this study is completely voluntary. Your decision whether or not to participate will not affect your current or future relations with St. Cloud State University, or the researcher. If you decide to participate, you are free to withdraw at any time without penalty.

If you have questions about this research study, you may contact Liping Ma at lma@stcloudstate.edu or my advisor, Dr. Ettien Koffi at enkoffi@stcloudstate.edu

Your signature indicates that you are at least 18 years of age, you have read the information provided above, and you have consent to participate.

______________________________________ ____________________

Signature

Date

St. Cloud State University
Institutional Review Board
Approval date: 3-19-2018
Expiration date: 3-18-2019