The Production and Perception of English Vowels by Native Speakers of Brazilian Portuguese Living in Victoria, Canada

by

Silas Romig
B.A., University of Alaska Anchorage, 2013

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTER OF ARTS

in the Department of Linguistics

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Supervisory Committee

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Abstract

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This thesis focuses on the production and perception of ten English vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/) by native speakers of Brazilian Portuguese (BP) living in Victoria, British Columbia, Canada. The participants consisted of 14 native speakers of BP (divided into intermediate and advanced second language (L2) English proficiency groups), plus six native speakers of Canadian English (CE) as control participants. Four experiments were carried out: two pertaining to production and two pertaining to perception. The production tasks consisted of CE and BP wordlist reading tasks in order to measure the duration and first two formants of the participants' vowels, while the perception tasks consisted of an identification task and an oddity-discrimination task. With regards to production, this thesis investigates how the participants' productions of the L2 vowels differ between the experimental and control groups with respect to their formant frequencies and the Euclidean distances (EDs) between various English vowel pairs. Similarly, the participants' perceptual abilities, as measured by their performance on the perception tests, are examined. Finally, the connection between perception and production is investigated. The findings indicate (a) a positive effect of proficiency, as the advanced participants showed a greater ability to both produce and perceive the L2 vowels, but that (b) participants of both proficiency levels have difficulty in contrasting certain English vowel pairs in a native-like fashion. Furthermore, the findings provide evidence of a connection between perception and production, and show that perception outperforms production, as predicted by the Speech Learning Model (Flege, 1995, 2005). Finally, the findings indicate a possible positive effect of environment (i.e., an English-speaking country) when compared to previous studies (Bion et al., 2006, Rauber, 2006). Pedagogical implications of these findings are also discussed.

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Dedication

This thesis is dedicated to my late father John Frederick Romig, whose love and support I can still sense. My thoughts always turn to him upon reaching any milestone in my life.

1. Introduction

A major part of a language's phonology lies in the sounds and sound distinctions that constitute its phonemic inventory. Nonnative speakers often have considerable difficulty in accurately perceiving and producing these sound distinctions in a language when they differ from those of their first language (L1). By studying how learners of a second language (L2) perceive and produce these sound distinctions and how their acquisition is influenced by different variables (e.g., proficiency level, L1 background), I am hoping to learn more about the process of L2 acquisition. The study of how native speakers of Brazilian Portuguese (BP) produce and perceive the vowels of Canadian English (CE) is an area that shows great potential for the study of L2 phonetics and phonology due to the significant differences between the languages' vowel systems and the lack of research on learners of different proficiency levels and learners living in English-speaking countries (cf. Baptista, 2006; Bion, Escudero, Rauber, & Baptista, 2006; Rauber, Escudero, Bion, & Baptista, 2005).

While several studies have examined native BP speakers' production and perception of the English vowels (e.g., Bion et al., 2006; Rauber et al., 2005) they have all, with few exceptions (i.e., Baptista, 2006; Souza, 2012), focused on advanced English as a Foreign Language (EFL) speakers who have never lived in an English speaking country. In the present study I have investigated the production and perception of the English vowels by native BP speakers of different proficiency levels living in Victoria, British Columbia, Canada, thereby presenting new, empirical data on how vowel distinctions are manifested in the interlanguage (IL) of these speakers and exploring

possible factors that could play a role upon this IL when compared to the above mentioned data of Rauber (2006), Bion et al. (2006), etc.

In order to investigate the production and perception of the CE vowels by native speakers of BP, experiments were conducted with three groups of participants: L2 learners with an intermediate proficiency level (i.e., the first experimental group), L2 learners with an advanced proficiency level (i.e., the second experimental group), and native speakers of English (i.e., the control group). The experiments consisted of an English reading task in order to test the participants' production of the ten CE vowels, a BP reading task (administered only to the experimental participants) as a means of comparison, a discrimination task, and an identification task (in order to test the participant's perception of the CE vowels). Three sets of guiding research questions were posed, one dealing with production of the CE vowels, one dealing with the perception of the CE vowels, and a third dealing with the connection between production and perception:

1. Concerning production of CE vowels, how will the experimental groups' productions–as measured in terms of formant frequencies, vowel durations, and Euclidean distances between vowel pairs–of the English L2 vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/) differ between the intermediate and advanced learner experimental groups and the native English speaker control group? How will the participants' productions of the L2 vowels compare to their productions of the L1 BP vowels (/i, e, ɛ, a, ɔ, o, u/)?

2. Concerning CE vowel perception, how accurately will the participants be able to identify the CE vowels in the identification task? How accurately will all participants

discriminate the English vowel pairs during a discrimination task? How will the rates of accurate discrimination differ between the two experimental groups and the control group?

3. What is the relationship between the production and perception of English vowels by native BP speakers and how does this relationship between production and perception differ between the intermediate learner and advanced learner groups?

The present thesis investigates the production and perception of the CE vowels by native speakers of BP with the goal of answering the above research questions. It is organized into six chapters, of which this introduction constitutes the first.

In Chapter 2, a description of relevant background information regarding the analysis of acoustic data (i.e., the measurement of formants, vowel durations, and Euclidean distances) is provided. Then, I describe both the BP and CE vowel systems and their acoustic properties, as well as compare the two systems. Next, I review some influential theoretical models–namely the Speech Learning Model (Flege, 2005) and Perceptual Assimilation Model (Best, 1995)–for the production and perception of nonnative sounds. Finally, relevant studies pertaining to the production and perception of English vowels by native speakers of BP are reviewed.

In Chapter 3, the research questions and the hypotheses generated from these questions are described. Next, I provide describe the participants recruited for this study and the instruments used to collect the data, along with the data collection procedure and methods of analysis.

In Chapter 4, the results of the production tasks are provided. Then, an analysis and discussion of these results are presented in order to confirm or reject the study's hypotheses. Both the results and analysis sections are divided into subsections by group (i.e., the native speaking control group, as well as the intermediate proficiency and advanced proficiency speakers).

In Chapter 5, the results of the perception tasks are presented, along with an analysis and discussion of the data generated from these tasks. Like the previous chapter, the analysis and discussion attempt to confirm or reject the hypotheses of this study.

In Chapter 6, a discussion of the findings of this study is provided in light of the study's research questions, hypotheses, and previous research. Then, pedagogical implications of these findings are discussed, as well as possible directions for future research.

2. Literature Review

In the following literature review I first provide definitions for key terms and concepts used throughout this study. Secondly, a comparison of the vowel systems of Brazilian Portuguese (BP) and Canadian English (CE)–both in terms of their phonological and phonetic properties–are given in order to provide adequate background knowledge. Thirdly, I give a description of prominent theoretical models of L2 speech production and perception that inform the research questions, hypotheses, and interpretations of the results in this study. Finally, I provide an overview of relevant research into the production and perception of English vowels by nonnative speakers. While studies in the field of speech production and perception abound, this review is limited to studies that focus on native speakers of BP learning English.

2.1 Definition of Key Terms

Interlanguage (henceforth IL) is the linguistic system that a language learner develops while learning an L2 (González, 2008). It may contain elements of both the learner's L1 and L2, or may contain novel elements. While the IL of a learner naturally develops and changes over time as their proficiency in their L2 increases, the IL is still a system that follows rules, rather than simply an incorrect usage of the L2.

The present study relies upon the measurement of formants in order to describe the BP, CE, and IL vowel tokens produced by the experimental and control participants. Formants are the acoustic resonances that occur within the vocal tract and form vowel sounds (Colantoni, Steele, & Escudero, 2015). These resonances are changed by altering the position of the tongue, jaw, and lips, thereby producing different vowel sounds.

Measuring these resonances (i.e., the formant frequencies) using the acoustic Hertz (Hz) scale allows the researcher to show where vowels are produced within the participant's vocal tract, or vowel space. More specifically, the first formant (F1) corresponds to the height of the vowel and the second formant (F2) corresponds to the backness of the vowel. Figures 1 and 2 illustrate how these formants appear on a spectrogram: In Figure 1, the low F1 (the dark line at the bottom of the spectrogram around 400 Hz) and high F2 (the next dark line near the middle of the spectrogram around 2300 Hz) indicate that the vowel being produced is high and front in the participants's vowel space (i.e., /i/). While in Figure 2, the low F1 (around 450 Hz) and low F2 (around 1300 Hz) indicate that the vowel being produced is high and back in the subject's vowel space (i.e., /u/).

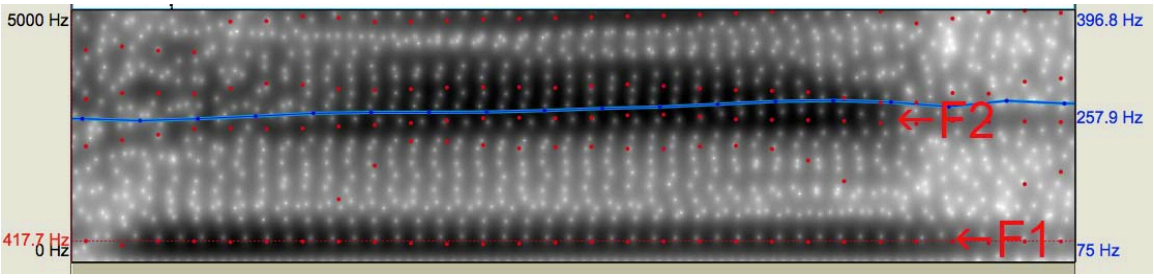

Figure 1. Spectrogram of English /i/ as produced by a female native speaker of BP with arrows indicating locations of F1 and F2.

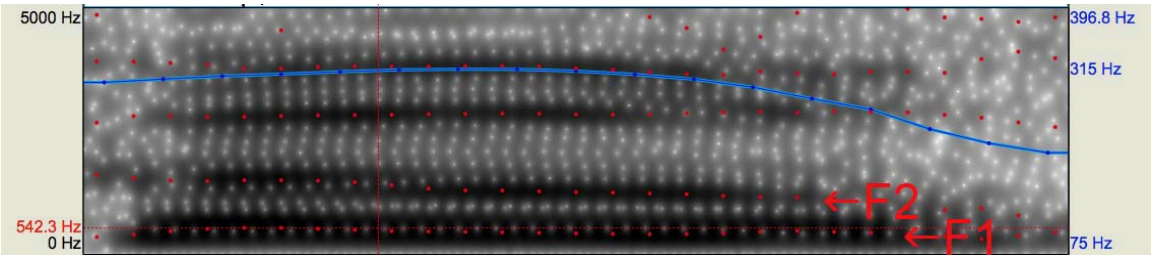

Figure 2. Spectrogram of English /u/ as produced by a female native speaker of BP with arrows indicating locations of F1 and F2.

2.2 The Vowel Systems of BP and English

2.2.1 The vowels of BP. While the focus of this study is upon the production and perception of Canadian English vowels by Brazilian learners, it is nevertheless necessary to briefly review the vowel system of BP, both in terms of its phonemic inventory as well as the acoustic properties of the vowels within that inventory.

2.2.1.1 Vowel phonemes of BP. BP phonemically contrasts seven oral vowels occurring in four degrees of height in stressed position /i, e, ɛ, a, ɔ, o, u/ (Câmara, 1970; Moraes, Callou, & Leite, 1996).[1] Table 1 below provides an illustration of this vowel system and Table 2 provides examples of the vowels in BP.

Table 1. The Brazilian Portuguese Vowel System

	Front	Central	Back
High	/i/		/u/
Mid-high	/e/		/o/
Mid-low	/ɛ/		/ɔ/
Low		/a/	

Table 2. Brazilian Portuguese Word List

/i/	/s**i**m/	*sim*	'yes'
/e/	/s**e**/	*sei*	'(I) know'
/ɛ/	/s**ɛ**ku/	*seco*	'dry'
/a/	/s**a**ku/	*saco*	'bag'
/ɔ/	/s**ɔ**ku/	*soco*	'a punch'
/o/	/b**o**la/	*bola*	'cake'
/u/	/s**u**ku/	*suco*	'juice'

There also exist five phonetically contrastive nasalized allophones of the oral vowels /ĩ, ẽ, ɐ̃, õ, ũ/, as well as a variety of diphthongs consisting of a combination of the vowels and the glides [w] and [j] (e.g., *fui* /fuj/ "I went"; *viu* /viw/ "he saw"). However,

[1] While some scholars (Barbosa & Albano, 2004) have found the vowels /ɪ, e̞, ɐ, ʊ/ to occur as allophones in post-stressed position in some dialects of BP (e.g., urban São Paulo), the present study assumes the seven vowel system proposed by others.

because this study deals with the acquisition of English oral monophthongs, the nasal vowels and diphthongs of BP will not be examined in-depth.

2.2.1.2 Acoustic properties of the BP vowels. While there exist several studies that describe the acoustic properties of BP vowels in terms of their durations and F1 and F2 frequencies, they are not without their limitations. A study by Callou, Moraes, and Leite (1996) provides the F1 and F2 values for the BP vowels as spoken by native speakers from five distinct areas of Brazil: Recife and Salvador in northern Brazil, Rio de Janeiro and São Paulo in southeastern Brazil, and Porto Alegre in southern Brazil (see Figure 3). However, the authors only collected data from male speakers, and only three speakers per dialect group at that. Furthermore, while the published figures provide some overview of the speakers' vowel spaces, they do not provide an adequate baseline for comparison due to the lack of exact formant values.

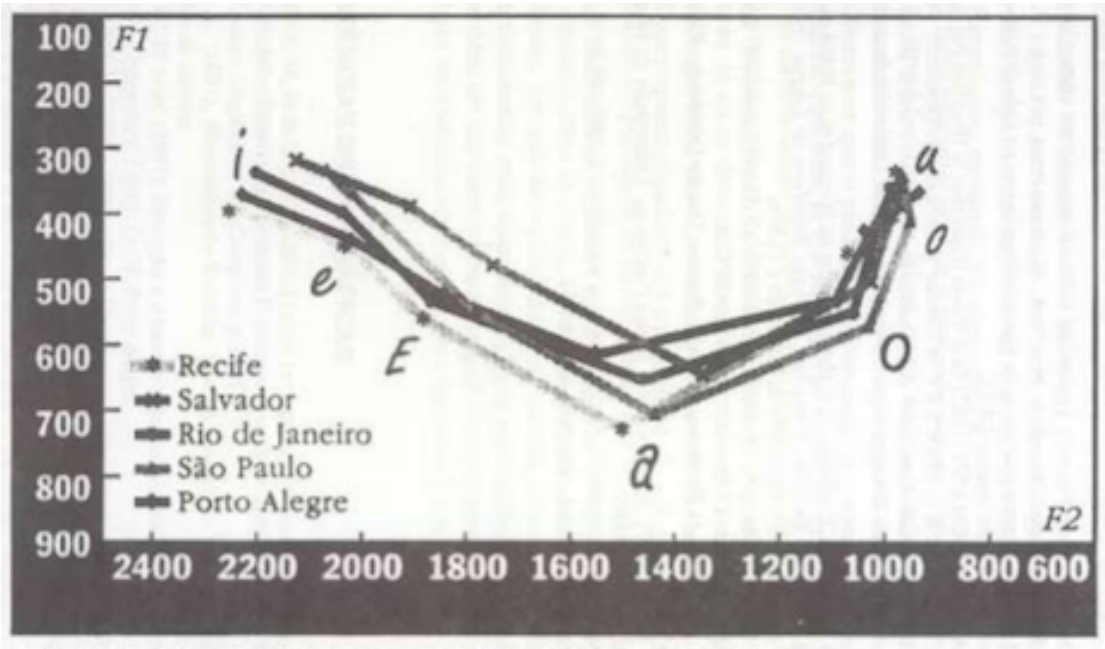

Figure 3. Mean formant values for the stressed vowels of BP by region. Reprinted from Callou et al. (1996)

The doctoral dissertation of Brito dos Santos (2013) provides data that are somewhat more useful than those of Callou et al. in that the exact F1 and F2 values and duration are provided for 10 native speakers of BP (5 male, 5 female). However, the participants in this study differ from those of the present study in that they were all from around the same city (i.e., Fortaleza dos Nogueiras, Maranhão) and were all over the age of 50. Furthermore, the author made no attempt to normalize her data. Nevertheless, these measurements (displayed below in Table 3) are useful as a means of comparison for the present study.

Table 3. Mean Formant Values and Duration for BP Vowels

	Male			Female		
Vowel	F1 (Hz)	F2 (Hz)	Duration (ms)	F1 (Hz)	F2 (Hz)	Duration (ms)
/i/	322	2159	100	415	2536	101
/u/	384	865	117	412	873	125
/e/	486	2008	122	536	2416	122
/ɛ/	614	1591	105	642	2243	136
/o/	440	832	116	497	879	128
/ɔ/	581	998	134	622	1033	116
/a/	726	1369	124	824	1553	111

Note. Adapted from "Análise fonético-acústica das vogais orais e nasais do português: Brasil e Portugal," by G. Brito dos Santos, 2013, unpublished doctoral dissertation.

2.2.2 The vowels of CE. While descriptions of the Canadian and American English (AE) vowel systems vary, it was initially decided that this study would focus upon the eleven vowels occurring in stressed position identified by Rauber et al. (2005), as the experiments in this investigation are partially adapted from their work. After an initial pilot study (Romig, 2016) this number was reduced to ten vowels, due to the vowels /ɑ/ and /ɔ/ (e.g., *sot* and *sought*) being merged in the English of western Canada (cf. 2.2.2.2). This section provides a general discussion of the English vowel system as it occurs in much of English-speaking North America, as well as dialect features more characteristic

of western Canada, as this is the input to which my participants have been exposed. An in-depth discussion of the acoustic properties of CE vowels–in terms of their formant values and durations– as exhibited by the control participants of this study is included in Chapter 4.

2.2.2.1 Vowel phonemes of CE. As mentioned above, there exist ten monophthongal vowel phonemes in CE as it is spoken in western Canada. These vowels are /i, ɪ, e, ɛ, æ, u, ʊ, o, ʌ, ɑ/. Table 4 below displays a near minimal pair wordlist for the monophthongal vowel phonemes of CE.

Table 4. CE Monophthongal Vowel Phonemes

/i/	*beat* **/bit/**	**/u/**	*boot* **/but/**
/ɪ/	*bit* **/bɪt/**	**/ʊ/**	*book* **/bʊk/**
/e/	*bait* **/bet/**	**/o/**	*boat* **/bot/**
/ɛ/	*bet* **/bɛt/**	**/ʌ/**	*but* **/bʌt/**
/æ/	*bat* **/bæt/**	**/ɑ/**	*bot* **/bɑt/**

2.2.2.2 Dialectal properties of the CE vowels. A particularly noteworthy feature of the vowel system of CE is the Canadian Shift (Labov, Ash, & Boberg, 2006), in which the low-back vowels /ɑ/ and /ɔ/ (i.e., the *cot-caught merger*) are merged into the low back vowel /ɑ/, triggering a shift in the vowel space. This shift results in a retraction of /ɛ/ and /ɪ/, a retraction and lowering of/æ/ and a centralization of /u/, /ʊ/, and /ʌ/ (Hagiwara, 2006). Figure 4 illustrates these dialectal properties of CE by comparing the mean formant values of the present study's male control participants with mean male formant values of General American (GA) speakers taken from Hillenbrand et al. (1995).

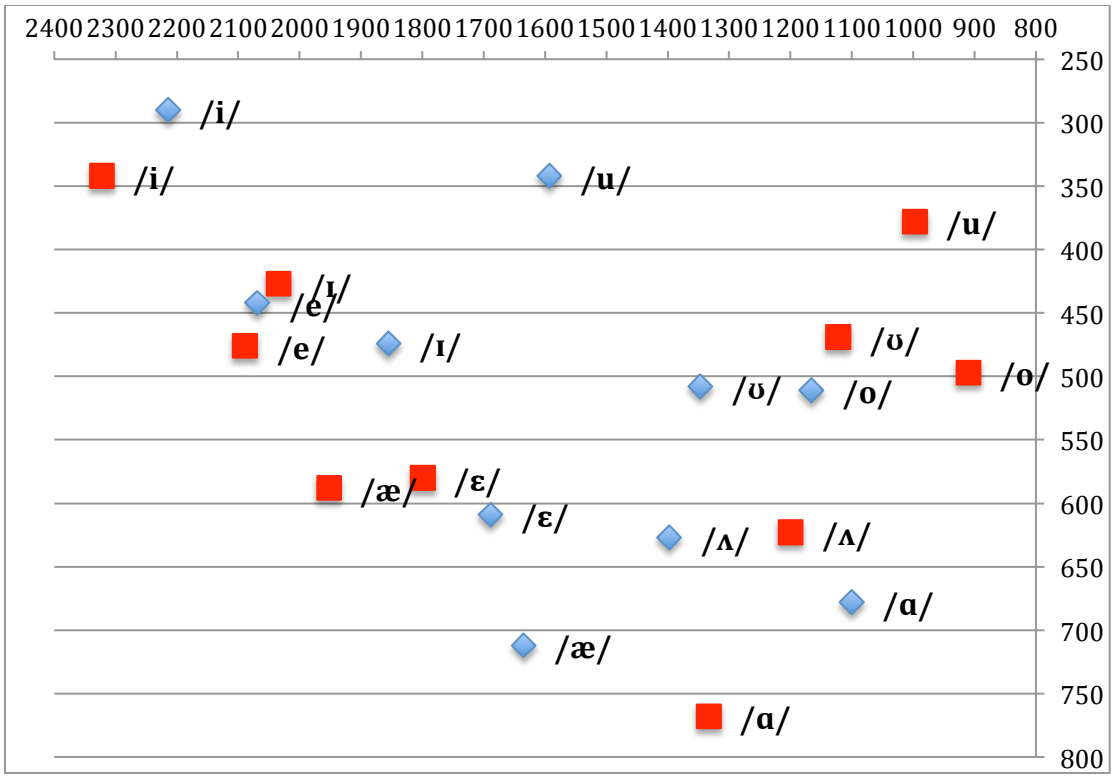

Figure 4. Scatter plot displaying the mean formant values of male CE speakers (blue diamonds) and male GA speakers (red squares). GA data is taken from Hillenbrand et al. (1995)

2.2.3 A comparison of the BP and CE vowels. From the preceding sections it should be apparent that BP and CE differ in terms of the quantity of vowels in their phonemic inventories. BP contains seven monophthongal phonemes, while CE contains ten. Using the terminology of Flege's (1995) Speech Learning Model (cf. Section 2.3.1), these inventories may be further compared by dividing the phonemes into three groups: those that are *new* (i.e., only exist in the L2 inventory), those that are *similar* (i.e., exist in both inventories, but differ in their articulatory and acoustic properties), and those that are *identical*.

The five CE vowels that do not occur as phonemes in BP are /ɪ, æ, ʊ, ʌ, ɑ/, although /ɪ/ and /ʊ/ may occur in post-stressed position in some dialects of BP (Barbosa

& Albano, 2004). The first three of these vowels are the lax counterparts to the tense vowels /i/, /e/, and /u/, respectively, and are features of the contrastive tenseness that exists in English. There exist no counterparts to these vowels in the phonemic inventory of BP. The fourth, /ʌ/, is a low-mid back central unrounded vowel that occurs higher in the vowel space than its BP counterpart /a/ (low front unrounded). The fifth, /ɑ/, is a low back unrounded vowel that occurs lower and more forward in the vowel space than its BP counterpart /ɔ/ (low-mid back rounded).

The remaining vowels (/i, e, ɛ, u, o/) occur in both inventories, but possess different acoustic properties, making them *similar*. In Figure 5, which shows the mean formant values for the CE and BP vowels as spoken by the male control participants and male experimental participants respectively, one can observe these acoustic differences. The centralized /u/ and retracted /ɛ/ characteristic of the Canadian Shift (§ 2.2.2.2) are readily apparent, CE /o/ occurs more forward and lower in the vowel space, CE /i/ is higher and more front, and CE /e/ occurs somewhat lower and more fronted than BP /e/.

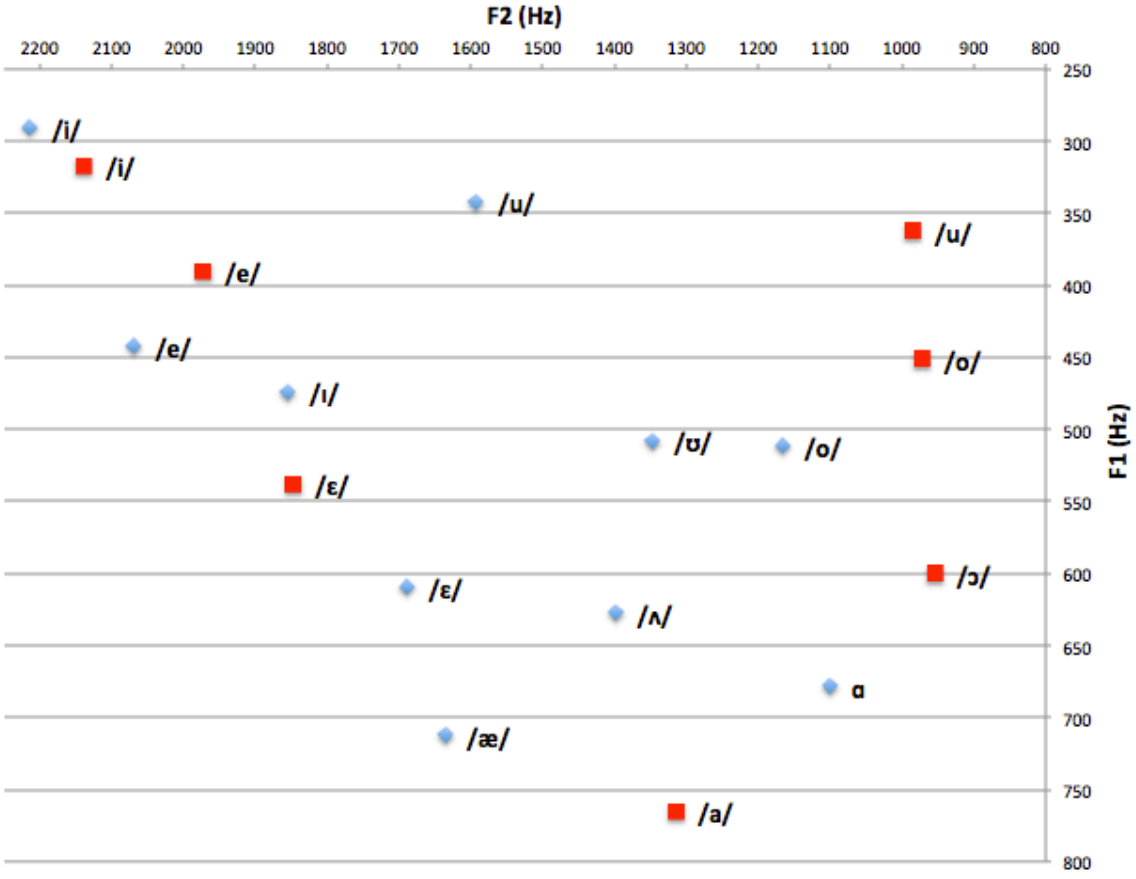

Figure 5. Scatter plot displaying mean CE (blue diamonds) and BP (red squares) formant values for male English L1 control participants (*N* = 3) and male BP L1 experimental participants (*N* = 5).

2.3 L2 Speech Production and Perception Models

Two of the current, influential theoretical models for the production and perception of nonnative sounds are Flege's Speech Learning Model (SLM) (Flege, 1995, 2005) and Best's Perceptual Assimilation Model (PAM), as well as Best and Tyler's extension of PAM: PAM-L2 (Best & Tyler, 2007). It should be noted that all of the relevant studies covered in Section 2.4 of this literature review utilize one or both models in their explanation of the production and perception of L2 vowels. The present study

primarily works within the framework of the SLM and its hypotheses, and thusly treats it with more depth.

2.3.1 Flege's Speech Learning Model (SLM). Flege's SLM claims that L2 learners can accurately perceive (and produce) the properties of L2 vowels, but that accomplishing this task takes time and is "importantly influenced by the nature of the input received" (Flege, 2005, p. 86). Furthermore, Flege postulates that the mechanisms and processes that guide L2 sound acquisition are the same that guide L1 acquisition and remain intact across the life span. The phonetic elements of the L1 and L2 subsystems exist in the same phonological space and influence one another (L1 and L2 transfer).

Flege generates several hypotheses from these aspects of the SLM. The first is that a new phonetic category is more likely to be formed for an L2 sound if it is perceived as being dissimilar from the closest sound in the L1. The second hypothesis states that the development of new phonetic categories for L2 sounds becomes less likely through childhood, as the neighboring L1 sounds develop. The third hypothesis is that when a new phonetic category is not formed for an L2 sound due to it being too similar to an L1 counterpart, the L2 and L1 sounds will assimilate or merge into an intermediary form. Flege also hypothesizes that the interaction between L1 and L2 sounds in the vowel space plays a role in whether a new phonetic category will be formed.

An illustration of some of these hypotheses (the first, third, and fourth) is provided below in Figure 6, which depicts the assimilation of a 10-vowel L2 system to a 7-vowel L1 system. As can be observed from the figure, new phonetic categories are formed for four vowels, three of which are then dissimilated from existing L1 vowels. No new phonetic category is formed for six of the L2 vowels, resulting in the L2 vowels and

their L1 counterparts undergoing assimilation and merging into an intermediary form. The fourth new phonetic category is then formed in the space formerly occupied by L1 vowels that have merged with their L2 counterparts.

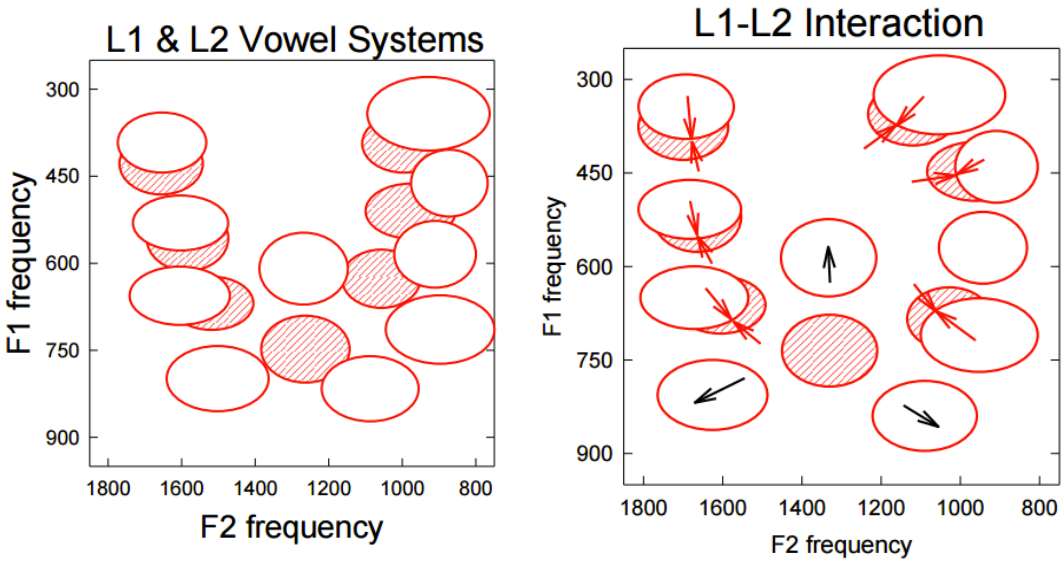

Figure 6. (Left) A 7-vowel L1 system (filled ellipses) and a 10-vowel L2 system (unfilled ellipses). (Right) An illustration of the assimilation and dissimilation of L2 sounds in the vowel space. Reprinted from Flege (2005).

Of particular relevance to the study of English vowel production by Brazilian EFL speakers is the SLM's claim that while learners may establish a new phonetic category for sounds that are completely different than any in the L1 sound system, sounds that are similar will be perceived as an L1 category. In other words, the greater the perceived dissimilarity, the more likely a new category will be formed. In the case of the English vowels as perceived by Brazilian EFLs, this would likely result in a difficulty distinguishing pairs of vowels such as /ɛ/ and /æ/ due to their phonetic similarity and is supported by the literature (e.g., Rauber, 2006).

2.3.2 Best's Perceptual Assimilation Model (PAM) and Best and Tyler's PAM-L2.

Best's PAM is similar to the SLM in that it attempts to describe the mapping of L2 sounds into the same phonological space as the L1 (Best, 1995). However, rather than describe the process in terms of L2 sounds that are either different or similar to L1 sounds, it proposes several types of assimilation. Of particular relevance to the perception of English vowels by native BP speakers are the processes of Two-Category assimilation in which two L2 sounds are heard as two distinct L1 sounds and the contrast between them is therefore easily perceived, Single-Category assimilation, in which two L2 sounds are heard as the same L1 phoneme and therefore difficult to distinguish, and Both Uncategorizable, in which two L2 sounds are completely different from any L1 phoneme and may be easy or difficult to distinguish.

PAM was initially designed in order to explain nonnative speech perception by naïve (i.e., inexperienced) listeners, but not those with experience (i.e., L2 learners). An extension of PAM, PAM-L2, was designed to address this shortcoming of the original framework (Best & Tyler, 2007). PAM-L2 resembles something of an intermediary between PAM and the SLM in that it postulates the same assimilation processes describes in PAM (e.g., Two-Category, Single-Category, etc.), but applies them to experienced listeners. However, PAM-L2 differs from the SLM in that it addresses equivalence at both the phonetic and phonological level, rather than just the phonetic level.

2.4 Previous Studies on English Vowel Production/Perception by Brazilians

Although much has been written on the production and perception of English vowels by nonnative speakers of the language (e.g., Flege, Bohn, & Jang, 1997; Munro & Derwing, 2008) there remains little research that examines native speakers of Portuguese specifically. What does exist focuses either on a single proficiency level (i.e., advanced) (Bion et al., 2006; Rauber et al., 2005; Rauber, 2006), solely on production of the English vowels (Baptista, 2006), or on a limited set of vowels (Souza, 2012).

In Bion et al. (2006) the authors examine the category formation of the American English front vowels (/i/, /ɪ/, /ɛ/, and /æ/) by native speakers of Brazilian Portuguese as well as the role of spectral quality in the perception and production of these vowels. In this study the authors seek to determine whether there is a correlation between accurate perception and production of the English vowel pairs and whether "native-like use of spectral quality when perceiving English vowels is a prerequisite for reliable category perception" (p. 1363). In other words, the researchers investigate whether accurate perception of English L2 vowels requires that learners possess the ability to distinguish vowels based upon their spectral quality (i.e., their formants), or whether they may reliably perceive them based upon other acoustic cues (e.g., duration). They accomplish this by conducting three experiments (one production test and two perceptual tests) with an experimental group of 17 highly proficient Brazilian speakers of English as a second language and a control group of six native English speakers. These experiments consist of a production test in which the first two formants of the participants' vowel production were measured, and two perception tests, one consisting of an oddity discrimination test in order to investigate the formation of vowel categories, and the other consisting of a

discrimination test to determine the participants' reliance on spectral quality in their perception of the English front vowels. The findings of these experiments and their analysis suggest that there is a strong relationship between vowel production and perception, that vowel perception may precede production, and that acoustic cues other than spectral quality (e.g. vowel duration) might play a role in vowel perception for Brazilian speakers of English as a second language.

Rauber et al. (2005) examines the relationship between the production and perception of the American English vowels (/i, ɪ, ei, ɛ, æ, ʌ, ɑ. ɔ, oʊ, ʊ, u/) by Brazilian speakers. It follows a very similar design to the Bion et al. (2006) study in that it consists of a production test to measure the formant levels of the participants' vowels, as well as an oddity discrimination test to test their perception of the vowels. Like Bion et al. (2006), the participants for this study consisted of 16 highly proficient Brazilian speakers of English, all of whom had over five years of experience teaching English at the time of data collection. The study differs from that of Bion et al. in that it also measured the production of the Brazilian Portuguese vowels (/i, e, ɛ, a, ɔ, o, u/) in order to compare their production with that of the English vowels. The results of the production experiment showed that participants, despite their high proficiency in English, drew upon the vowel system of their L1 in producing the English vowels, resulting in contrasts that differed from those of native English speakers. More specifically, the authors reported that 50% of participants produced a distinction between /i/ and /ɪ/, 56.25% produced a distinction between /ɪ/ and /e/, 56.25% produced a distinction between /ɑ/ and /ɔ/, /o/ was produced similarly to BP /o/ (i.e., too high), 18.75% produced a distinction between /u/ and /ʊ/, and no participants produced a distinction between /ɛ/ and /æ/. However, it should be noted

that the authors provide no explanation has to how they determined these rates of distinction and only provide the F1 and F2 values of the BP, IL, and L1 English vowels for comparison. Regarding perception, the results of the perception test revealed that participants discriminated vowel contrasts with varying degrees of accuracy. The /ɛ/-/æ/, /ʊ/-/u/, and /ɔ/-/ɑ/ vowel pairs were accurately discriminated by less than 55% of the participants and the /ʌ/-/ɑ/ contrast was the most poorly discriminated at 20.83% (possibly due to the small F1/F2 differences between the two vowels), while the /i/-/ɪ/ was the most accurately discriminated at 93.83%, and the /ʊ/-/ʌ/ pair was discriminated 71% of the time. Interestingly, contrasts involving the semi-diphthongs /e/ and /o/ were discriminated over 85%, with the authors claiming that slight diphthongization probably serves as a perceptual cue. Finally, the authors concluded that the assimilation of two English vowels (e.g., /ɛ/ and /æ/) into a single phonetic category (e.g., /ɛ/) is to blame for the participants' difficulty in producing and distinguishing the L2 vowels and that inaccurate production is related to inaccurate perception.

In Rauber's (2006) unpublished doctoral dissertation, the author conducts a study that could best be viewed as an expansion upon her previous work (i.e., Bion et al. 2006, Rauber et al., 2005). Like the aforementioned studies, Rauber's dissertation investigates the production and perception of American English vowels by advanced Brazilian EFL speakers who have never lived in an English speaking country. However, it differs in that it draws data from both monolingual (American English and Brazilian Portuguese) speakers in addition to bilingual speakers. While data from all American English, Brazilian Portuguese, and EFL vowels were gathered, Rauber focuses upon the pairs /i/-/ɪ/, /ɛ/-/æ/, and /u/-/ʊ/, as Brazilian EFL speakers generally have the most difficulty in

distinguishing between them in production and perception. Her results indicate that the Brazilian EFL speakers distinguished the vowel pairs, in both production and perception, in the following descending order: /i/-/ɪ/, /u/-/ʊ/, /ɛ/-/æ/. Table 5 below shows the rate of similarity of the Euclidean distance (ED) between the vowel pairs produced by the male L2 participants and the control participants, thereby providing an illustration of the L2 participants' ability to distinguish the vowel pairs.[2] As can be observed from the table, the /i/-/ɪ/ pair most closely approximated the control participants (59.5% in production and 94% in perception) and the /ɛ/-/æ/ pair proved the most difficult to distinguish (19.8% in production and 50.0% in perception).

Table 5. Rates of similarity of the Euclidean distance between the vowel pairs produced and perceived by the male L2 participants

Vowel Pair	Production ED AE-L2	Perception ED L2 (Hz)
/i/-/ɪ/	59.5%	94.0%
/ɛ/-/æ/	19.8%	50.0%
/u/-/ʊ/	25.7%	67.5%

Note. Adapted from "Perception and Production of English vowels by Brazilian EFL speakers," by A. Rauber, 2006, unpublished doctoral dissertation.

Furthermore, Rauber's study concludes that there exists a relationship between vowel perception and production, and that L2 perception outperforms L2 production.

The work of Baptista (2006) differs from that of the other current studies on the production of English vowels by native BP speakers in that she focuses on beginner learners living in an English speaking country (i.e., the United States). In this longitudinal study the author conducted a vowel production test with 11 participants who had recently arrived in California once a month for four to eight months. The production test consisted of a word list containing 42 monosyllabic English words containing the target vowels /i/,

[2] "Euclidean distance" refers to the distance between two points in a two-dimensional plane. In the present study and all studied citied, this plane is defined by F2 along the x-axis and F1 along the y-axis, with the distance being measured in Hertz (Hz). See Section 3.5.2 for the formula used to calculate ED.

/ɪ/, /eɪ/, /ɛ/, /æ/, /ɑ/, and /ɔ/, as well as a list of 24 Portuguese words containing the vowels /i/, /e/, /ei/, /ɛ/, /a/, and /ɔ/. The results of her study indicated that learners were able to construct an interlanguage (IL) vowel schema based off of the vowels of their native language, that new phonetic categories are formed for vowels which have no clear link with a NL vowel, and that the IL vowel system is adjusted over time so that the vowels more closely resemble the target L2 vowels and are more closely linked to one another, rather than being linked across systems to the NL (i.e., the IL become more defined as a separate vowel system, rather than an approximation of L2 vowels using preexisting categories). While this study provides valuable evidence of the formation of an L2 vowel system by learners living in an English speaking environment, it should be noted that it contained no experiment testing perception of L2 vowels and that it was limited to beginning learners (i.e., none of the participants were able to form a complete sentence in English without considerable difficulty at the beginning of the study).

Finally, the unpublished MA thesis of Souza (2012) studied the production and perception of the American English vowels /i/, /ɪ/, /ɛ/, and /æ/ (as well as the same vowels in nasalized environments) by 16 Brazilian English as a Second Language (ESL) learners with differing levels of proficiency, age of arrival in the US, and genders. Her results showed that proficiency played the greatest role in accurate production and perception of the American English vowels, and that the /i/-/ɪ/ contrast is harder to perceive and easier to produce, while the /ɛ/-/æ/ contrast is easier to perceive and harder to produce. The author postulates that the contrasting tenseness in the /i/-/ɪ/ pair makes it easier to distinguish than the /ɛ/-/æ/ pair, where both vowels are lax. However, it should be noted that the /ɛ/-/æ/ vowel pair was still more difficult to perceive and produce overall.

2.4 Summary

As can be observed from the research cited in Section 2.3, while there has been research into the production and perception of English vowels by Brazilians speakers of English as an L2, it has–to the best of my knowledge–been limited in scope, and there still exists the need for further research in order to address limitations of previous studies by examining new populations (i.e., L2 learners of varying proficiency levels living in an English speaking country). Rauber et al. (2005), Bion et al. (2006), and Rauber (2006) have focused solely on advanced (i.e., "highly proficient") L2 leaners who have never lived in an English speaking country, while Baptista (2006) focuses solely on the production of English vowels by beginner L2 learners living in the United States, and Souza (2012) only studied a limited set of English vowels. By designing the present study investigating the production and perception of English vowels by Brazilian L2 learners of different proficiency levels living in Canada, I intend to fill this gap in the literature and answer the research questions and hypotheses outlined in the following chapter.

3. Methods

3.1 Research Questions and Hypotheses

The focus of the present study is to investigate how native speakers of Brazilian Portuguese (BP) learning Canadian English (CE) as a second language (L2) produce and perceive the vowels of CE. To that end, this study is guided by the following research questions and hypotheses, which are organized by whether they address the issues of production, perception, or the connection between the two.

1. Concerning production of CE vowels, how will the experimental groups' productions–as measured in terms of formant frequencies, vowel durations, and Euclidean distances between vowel pairs–of the English L2 vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/) differ between the intermediate and advanced learner experimental groups and the native English speaker control group? How will the participants' productions of the L2 vowels compare to their productions of the L1 BP vowels (/i, e, ɛ, a, ɔ, o, u/)?

2. Concerning CE vowel perception, how accurately will the participants be able to identify the CE vowels in the identification task? How accurately will all participants discriminate the English vowel pairs during the discrimination task? How will the rates of accurate discrimination differ between the two experimental groups and the control group?

3. What is the relationship between the production and perception of English vowels by native BP speakers and how does this relationship between production and perception differ between the intermediate learner and advanced learner groups?

Based on the research questions above, the SLM (Flege, 1995, 2005), and the findings of previous studies (i.e., Bion et al., 2006; Rauber, 2006; Rauber et al., 2005) the following hypotheses regarding production and perception are tested:

Production:

A. L2 (CE) vowels that are *similar* to L1 (BP) vowels (i.e., those that occur in both inventories, but have different acoustic properties; /i, e, ɛ, u, o/) will be produced with formant values similar to the BP vowels in the intermediate group, and in the advanced group, they will be an intermediary between the BP and CE L1 vowels.

B. L2 (CE) vowels that are *new* (i.e., those that do not occur in the BP inventory, /ɪ, æ, ʊ, ʌ, ɑ/) will be produced with formant values similar to native speaker formant values in the advanced group and will not be acquired in the intermediate group.

C. New vowels that are too similar to an existing phonetic category will remain persistently difficult to acquire across the proficiency groups, with the existing L1 sound and new L2 sound eventually merging into an intermediary form rather than a new contrast being formed.

Perception:

D. L2 (CE) vowels that are similar to L1 (BP) vowels (/i, e, ɛ, u, o/) will be perceived accurately by both the intermediate and advanced groups, but new vowels (/ɪ, æ, ʊ, ʌ, ɑ/) will not be perceived well by the intermediate group.

E. Participants' perception will outperform their production, with participants being able to discriminate and identify some vowel contrasts that they are not able to produce reliably.

F. Perception and production will be linked, with vowel contrasts that are poorly perceived on the discrimination task being poorly produced in the production task. Similarly, vowels that show lower rates of identification on the identification task will be poorly produced.

3.2 Participants

Two different groups of participants were selected for this study. The first group consisted of Brazilian ESL speakers living in Victoria, BC. A speaking test based upon the International English Language Testing System (IELTS) speaking test was administered in order to further divide the experimental participants into intermediate and advanced proficiency groups (§ 3.3.2, 3.4.1, and 3.5.1). The second group consisted of native speakers of Canadian English and served as a baseline for comparison. All participants signed a standard informed consent document and were given a copy of the document, following the university's ethical guidelines.

3.2.1 Experimental Participants. Fourteen native speakers of BP, eight women and six men, were recruited for this study. The women's ages ranged from 24 to 39 years (M = 32.9 years, *SD* = 6.2 years), and the men's ages ranged from 20 to 44 years (M = 27.3 years, *SD* = 8.6 years). The participants originated from five states in Brazil: São Paulo (*N* = 6), Santa Catarina (*N* = 3), Minas Gerais (*N* = 2), Rio Grande do Sul (*N* = 2), and Rio de Janeiro (*N* = 1). All but three participants (IF2, AF1, and AM1) reported some experience with an L2 other than English, with eight participants having studied Spanish and three having studied French[3]. All participants were living in Victoria, BC at the time of data collection. More detailed information about each participant's background is displayed in Table 6. The names assigned to each experimental participant consist of an "I" or "A" (for intermediate and advanced, respectively; § 3.2.1.1 and 3.2.1.2), an "F" or "M" for the participant's gender, and a number.

Table 6. Brazilian Experimental Participants' Background Information

Participant	Age	Origin	Education	Occupation
IF1	39	Florianópolis, SC	MBA	Flight attendant
IF2	39	Belo Horizonte, MG	Bachelor's	Accountant
IF3	36	São Bernardo, SP	Bachelor's	Sales associate
IF4	27	Porto Alegre, RS	Bachelor's	Administrator
IF5	35	São Jose do Campos, SP	MBA	Financial
IM1	44	Belo Horizonte, MG	Master's	Judge
IM2	24	Ribeirão Preto, SP	Bachelor's	Engineer
IM3	28	Porto Alegre, RS	Postgraduate	Software developer
AF1	24	São Paulo, SP	Bachelor's	Student
AF2	37	Florianópolis, SC	Postgraduate	Entrepreneur
AF3	26	São Paulo, SP	Master's	Community worker
AM1	24	Florianópolis, SC	Bachelor's	Student
AM2	24	Santos, SP	Bachelor's	Journalist
AM3	20	Nova Friburgo, RJ	Some college	Student

[3] While the possible influence of these additional languages are acknowledged, their effects are left to future studies.

Additionally, participants reported their length of residence (LoR) in Canada, their scores on any standardized English tests (e.g., IELTS and TOEFL), self-reported English proficiency levels (on a scale of 1 to 5, with 1 being "poor" and 5 being "native-like"), hours per day they spent communicating in English ("hours of input," or HoI), and the age at which they began to acquire English ("age of onset of acquisition," AOA). Furthermore, participants reported their age when they were first exposed to English ("age of first contact," AoFC), which differs from the AOA of most participants.

However, while this information is useful in providing a full picture of the participants and their L2 experience, a formal assessment of language proficiency was used to divide the participants into two groups. As stated above, a speaking test based upon the IELTS speaking test was administered to all participants, and the results were rated by two native speakers of English (the author and another graduate student of linguistics, both experienced in teaching English as a foreign language; see Section 3.5.1 for more details regarding analysis of the IELTS tests).[4] Following the guidelines set by the Canadian Department of Immigration and Citizenship (CIC), participants who received a score of 7 or above on the speaking portion of the IELTS test were placed in the advanced group, and those that scored between 4 and 6 were placed in the intermediate group.

3.2.1.1 Intermediate English Proficiency Group. Eight participants, five women and three men, were determined to be of intermediate proficiency, with IELTS scores ranging from 4 to 6. As can be observed in Table 7, all intermediate participants with the exception of IF4 and IM3 reported an AoFC that differed from their AOA, with the

[4] Because IELTS testing materials are not made available to the public, a practice version of the speaking test was used. For this reason, the test is said to be "based upon" the IELTS, although it is essentially identical to the actual test.

majority of participants responding that while they had been exposed to English media or very minimal English instruction in grade school, their education had not begun in earnest until a later date. Furthermore, IF4 and IM3 are the only participants in the intermediate group who began to learn English before adulthood, with the overall mean AOA being 25.3. Finally, IF4 and IM3 have among the lowest LoR of all intermediate participants (2 months), while the remaining participants' LoR range from 2 months to 20 months with a mean LoR of 6.3 months.

Table 7. Intermediate Experimental Participant's English Experience Information

Participant	Age	IELTS	AoFC	AOA	LoR	HoI
IF1	39	4	30	30 (9 yr.)	3 mo.	4
IF2	39	4	11	39 (4 mo.)	4 mo.	6
IF3	36	5	16	28 (8 yr.)	20 mo.	15
IF4	27	6	9	9 (17 yr.)	2 mo.	6
IF5	35	6	15	18 (4 mo.)	4 mo.	9
IM1	44	4	10	42 (21 mo.)	2 mo.	5
IM2	24	5	14	24 (5 mo.)	5 mo.	5
IM3	28	6	12	12 (16 yr.)	2 mo.	8

Note. IELTS = Score on speaking test modeled after the IELTS; AoFC = Age of First Contact; AOA = Age of Onset of Acquisition; LoR = Length of Residence; HoI = Hours of Input

In addition to the data regarding their experience with English, participants provided their own self-assessments of their English proficiency (see Table 8). Participants were asked to rate their English speaking, listening, reading, and writing skills with a score from 1 to 5, with 1 being "poor" and 5 being "native-like." Overall, the intermediate group reported an average self-assessment score of 2.7 (*SD* = .83).

Table 8. Intermediate Experimental Participants' Self-Assessment Scores

Participant	Speaking	Listening	Reading	Writing	Mean
IF1	1	1	1	1	1
IF2	2	1	2	2	1.8
IF3	3	3	5	3	3.5
IF4	3	3	3	3	3
IF5	3	2	3	3	2.8
IM1	3	2	3	2	2.5
IM2	3	4	4	3	3.5
IM3	3	4	4	2	3.3
Mean	2.6	2.5	3.1	2.4	2.7

Note. Scores were based on a scale of 1-5, with 1 being "poor" and 5 being "native-like."

3.2.1.2 Advanced English Proficiency Group. Six participants, three women and three men, were determined to be of advanced proficiency, with IELTS scores ranging from 7 to 8. All advanced participants–with the exception of AF2–reported an AOA occurring before adulthood with the average AOA being 13.7 years (see Table 9). The LoR of the advanced participants also differed significantly from that of the intermediate participants. While the intermediate group only had one participant with an LoR over 6 months, the advanced group only had two participants (AF3 and AM2) with LoR under a year (mean LOR = 2.6 years). Finally, the advanced differed from the intermediate group in that the majority reported AoFC that were close or identical to their AOA.

Table 9. Advanced Experimental Participants' English Experience Information

Participant	Age	IELTS	AoFC	AOA	LoR	HoI
AF1	24	7	10	10 (14 yr.)	16 mo.	1-2
AF2	37	8	7	30 (7 yr.)	4 yr.	12
AF3	26	8	8	8 (18 yr.)	10 mo.	7
AM1	24	7	10	10 (14 yr.)	16 mo.	6
AM2	24	7	8	12 (12 yr.)	13 days	6-9
AM3	20	8	8	12 (8 yr.)	8 yr.	"All day"

Note. IELTS = Score on speaking test modeled after the IELTS; AoFC = Age of First Contact; AOA = Age of Onset of Acquisition; LoR = Length of Residence; HoI = Hours of Input

The self-assessment scores that the advanced group provided for their English speaking, listening, reading, and writing skills are displayed in Table 10. The average self-assessment score of the advanced group was 4.3 (*SD* = .47).

Table 10. Advanced Experimental Participants' Self-Assessment Scores

Participant	Speaking	Listening	Reading	Writing	Average
AF1	4	5	5	4	4.5
AF2	3	5	5	4	4.3
AF3	4	5	4	3	4
AM1	4	5	5	4	4.5
AM2	3	3	4	4	3.5
AM3	5	5	5	5	5
Average	3.8	4.7	4.7	4	4.3

Note. Scores were based on a scale of 1-5, with 1 being "poor" and 5 being "native-like."

3.2.2 Control Participants. Six Canadians, three women and three men, were recruited to complete the production and perception (identification and discrimination) tasks in order to provide baseline data for comparison with the experimental participants. The women's ages ranged from 20 to 32 years (M = 24 years, *SD* = 6.9), and the men's ages ranged from 21 to 28 years (M = 24.7 years, *SD* = 3.5). All participants were from Victoria, BC. While monolingual speakers of CE were sought for this study, this proved be a difficult task in a multilingual country such as Canada and, as a result, three participants reported having experience with an L2: two reported some experience with French, but with limited proficiency, and one reported extensive experience with Cantonese and minimal experience with Mandarin Chinese. Table 11 displays more detailed background information regarding the control participants. The names assigned to each control participant consist of a "C" (for control), an "F" or "M" for the participant's gender, and a number.

Table 11. Canadian Control Participants' Background Information

Participant	Age	Education	Occupation
CF1	20	Current university student	Student
CF2	20	Current university student	Student
CF3	32	Some college	Gasfitter apprentice
CM1	21	Some high school	Musician
CM2	25	High School Diploma	Baker
CM3	28	High School Diploma	Musician

3.3 Instruments

In order to test the participants' ability to produce and perceive the vowels of CE, four experiments were designed: two production tasks in which participants read a list of sentences (one list in English, the other in BP; with the control participants only reading the English list), an identification task in order to test the participants' ability to identify the CE vowels in isolation, and a discrimination task in order to test the participants' ability to discriminate contrastive CE vowels. Additionally, all participants completed a background questionnaire and the experimental participants were administered a speaking test adapted from the IELTS speaking test.

3.3.1 Background questionnaire. All participants were asked to complete a background information questionnaire (see Appendix A)—adapted from Swain, Huang, Barkaoui, Brooks, and Lapkin (2009)—before completing the speaking portion of the IELTS test. The questionnaire solicited information regarding the participants' experience with English in terms of AOA, LOR in English-speaking countries, self-assessment of language skills, and standardized test scores, as well as information regarding their place of birth, education, etc.

3.3.2 IELTS speaking test. Participants in the experimental groups were administered a test adapted from the speaking portion of the IELTS test (see Appendix B)

in order to formally assess their English proficiency. The test was adapted from a practice test and consisted of three parts, following the format of the IELTS speaking test. The first part consisted of questions regarding the participants' hometown (e.g., "What is the most interesting part of your hometown/village?") and lasted four to five minutes. In the second part, participants were asked to think of something that was important to them and were given one minute to prepare a one to two minute response describing the item, where they got it, why it is important to them, etc. Finally, the third part consisted of a discussion about what people value (e.g., "What kinds of things give status to people in your country?") and lasted four to five minutes.

3.3.3 Corpus for elicitation of English and BP vowel tokens. Participants in both the experimental and control groups (i.e. the native BP speakers and native CE speakers) were asked to read a list of sentences (see Appendix D)—adapted from Rauber (2006)—that acted as carriers for 60 words, including some nonce words, containing six tokens for each of the ten vowels of CE (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/). All words contained the vowel token occurring in mid-obstruent position to facilitate the segmentation of the token for acoustic analysis. The sentences in the list appeared in random order and were read once, resulting in 60 tokens (six tokens per vowel).

In addition to the corpus of English words, participants in the experimental groups were asked to read a list of sentences in BP (see Appendix E), also adapted from Rauber (2006). These sentences contain 70 words and nonce words containing ten tokens for each of the seven vowels of BP (/i, e, ɛ, a, ɔ, o, u/). These data were used in order to map the L1 vowel systems of the experimental participants and compare it with their L2 vowel

system, as well as determine whether new phonetic categories were established for similar CE vowels.

3.3.4 Stimuli for the identification of English vowels test. The stimuli for the identification test consisted of a forced choice identification test with a closed data set of words containing each of the ten CE vowels as possible responses (§ 3.4.3), in order to test the participants' ability to identify the 10 CE vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/). The test was designed using TP (Perception Testing/Training) software (Version 3.1; Figueiredo et al., 2012). The stimuli consisted of 30 trials (3 tokens for each of the 10 CE vowels, see Appendix F for a list of all 30 words). The stimuli were recorded by a 25-year-old, male, native speaker of English from the Victoria area. All token words were monosyllabic with the target vowel occurring in a mid-obstruent frame (e.g., *cat* for /æ/; *set* for /ɛ/) and were presented in random order.

3.3.5 Stimuli for the discrimination of English vowels. The stimuli for the discrimination test consisted of a categorical discrimination test (CDT), specifically an oddity discrimination test, in order to test the participants' discrimination rate of ten English vowel pairs: /i/-/ɪ/, /ɪ/-/e/, /e/-/ɛ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/o/, /o/-/ɑ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, and /ʌ/-/æ/. The test was designed using TP (Perception Testing/Training) software (Version 3.1; Figueiredo et al., 2012). Following the design of Rauber et al. (2005), the stimuli consisted of 120 trials of three items (eight trials for each of the ten vowel contrasts, plus four trials of ten non-contrasted vowels; see Appendix G for a list of all 120 trials). The stimuli was recorded by a 22-year-old, female, native English speaker from the Victoria area and consisted of the target vowels occurring in a mid-obstruent frame within the carrier sentence "Now I say_____". The sentences were then organized into trials of three

sentences, each trial containing either the same target vowel in each sentence or one odd item (i.e., a word containing a different vowel than the other two). The position of the odd item varied across the trials, sometimes occurring as the first, second, or third sentence.

3.4 Procedure

3.4.1 Procedure for the IELTS speaking test. After signing the informed consent document and completing the background questionnaire, participants were administered the IELTS speaking test. Participants who had not previously taken the IELTS test were given an explanation of what it entailed and were asked practice questions as a training exercise and demonstration of the test. Participants were then administered all three parts of the IELTS speaking test successively as described above in Section 3.3.2 (see Appendix B for a complete list of questions and prompts for the test) and were recorded with a Roland Cs-15s microphone connected to a Roland R-05 WAV/MP3 recorder. The entire test took approximately 9-12 minutes to complete.

3.4.2 Procedure for production test. After completing the IELTS speaking test, the participants were given an explanation of the tasks they would be asked to perform for the production test (i.e., they were asked to read the list of sentences provided in their natural speaking voice). All participants were recorded in a sound attenuated room at the University of Victoria using a Roland Cs-15s microphone connected to a Roland R-05 WAV/MP3 recorder. The recordings were sampled at 96.0 kHz and encoded as uncompressed 24 bit WAV files in order to ensure maximum sound quality.

3.4.3 Procedure for identification test. After completing the production test, participants were given an explanation and brief training of the procedure for the forced-

choice identification before completing the test on my computer using the test designed on TP (Perception Testing/Training) software (Version 3.1; Figueiredo et al., 2012). During this test, participants listened to the tokens described in Section 3.3.4 and were asked to choose the response option that contained the same vowel sound as what they heard from a list of ten token words (see Table 12). Participants were able to replay each stimulus a maximum of two times. The identification task took an average of 4.74 minutes for the intermediate group, an average of 4.14 minutes for the advanced group, and an average of 3.18 minutes for the control group.

Table 12. Response Options for Forced-Choice Identification Task

Vowel	Token Word	Vowel	Token Word
/**i**/	*sheep*	/**ʌ**/	*suck*
/**ɪ**/	*ship*	/**ɑ**/	*shot*
/**e**/	*date*	/**o**/	*joke*
/**ɛ**/	*bet*	/**ʊ**/	*book*
/**æ**/	*bat*	/**u**/	*boot*

3.4.4 Procedure for discrimination test. After completing the identification test, participants were given an explanation of the procedure for the CDT, as well as a brief training, before being asked to perform the test on my computer using the test designed on TP (Perception Testing/Training) software (Version 3.1; Figueiredo et al., 2012). During this test the participants listened to the trials of recorded stimuli described in Section 3.3.5 and were asked to check (A), (B), or (C) to indicate the odd item in the triad of tokens, or (D) if they perceived all items as being identical (e.g., "Now I say *teak*. Now I say *seek*. Now I say *sit*."). Participants were able to replay each trial a maximum of two

times. The test took an average of 32.62 minutes to complete, with the completion time not differing considerably across the experimental and control groups.

3.5 Data Analysis

3.5.1 IELTS test scores. In order to formally assess the English proficiency of the experimental participants, all IELTS test performances were recorded and rated by two raters. Both raters–one of whom being myself–were native speakers of English, graduate students of linguistics, and had had experience teaching English as a foreign language. The raters rated the tests independently of one another using the official IELTS speaking band descriptors (see Appendix C). Using this official assessment tool, the raters identified characteristics of the participants' speaking abilities across four categories: Fluency and Coherence, Lexical Resource at the word level, Lexical Resource at the structural level, and Pronunciation, as well as across nine proficiency levels (or bands). The raters assigned a score to each participant based upon their performance across each category (e.g. "speaks at length without noticeable effort or loss of coherence" would be characteristic of a band 7 speaker, while "is willing to speak at length, though may lose coherence at times due to occasional repetition, self-correction, or hesitation" would be characteristic of a band 6). After independently rating the participants, the raters met in person and compared results. Differing scores between raters were discussed until complete inter-rater agreement was established.[5]

3.5.2 Production test analysis. The vowel tokens of each participant were measured for a 25-millisecond window in the steady-state portion of the vowel's

[5] While the IELTS test allows for a discrepancy of one half point between raters, I opted for a more conservative inter-rater agreement rate of 100%.

duration, with the exception of the English semi-diphthongs /e/ and /o/, which were only measured by their first element before the beginning of the off-glide (Rauber, 2006; see Figure 7).

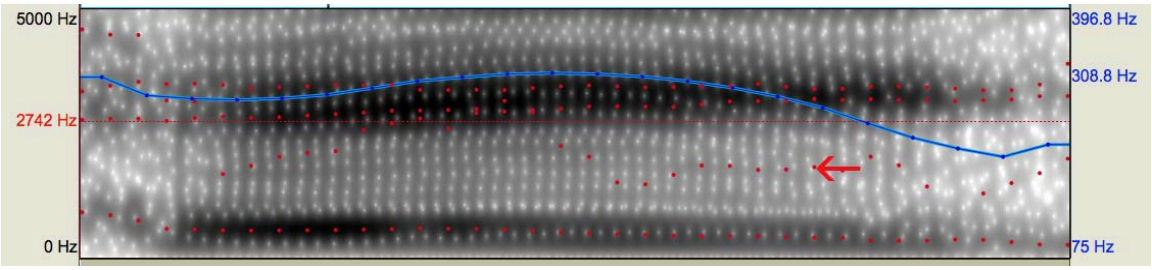

Figure 7. Spectrogram of *take* (/tek/) as spoken by a female native speaker of BP with the lowered F2 of the off-glide indicated by a red arrow.

The first and second formant (F1 and F2) values and duration of each vowel token were measured using Praat (Boersma & Weenink, 2017) and the mean values of each vowel's formants were charted on a scatter plot in order to show their position within the participants' vowel space. In addition to this general mapping of the vowel tokens, measurements were taken in Hz to show the ED between the vowel pairs /i/-/ɪ/, /ɪ/-/e/, /e/-/ɛ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/o/, /o/-/ɑ/ /ʊ/-/ʌ/, /ʌ/-/ɑ/, and /ʌ/-/æ/ (Bion et al., 2006; the formula used to measure Euclidean distance is listed below in 1).

$$\sqrt{(\mathrm{F1}_a - \mathrm{F1}_b)^2 + (\mathrm{F2}_a - \mathrm{F2}_b)^2} \quad (1)$$

The distances between the vowel pairs of the experimental participants were then compared to those of the control participants.

3.5.3 Perception tests analyses. The data collected from the identification and discrimination tests were quantified and organized to show the accuracy rates of identification for the vowels and rates of accurate discrimination between the vowel contrasts for each of the participants. The discrimination rates of the experimental participants were compared to one another, between the proficiency groups, and to the

results of previous studies (Rauber et al., 2005; Bion et al., 2006; Rauber, 2006) to investigate whether the rates of accurate production and perception differ between Brazilian L2 learners living in Canada versus those that have never lived in an English speaking country. The results of the perception test were also compared to the data gathered from the production test in order to investigate the relationship between production and perception.

4. Production Results & Analysis

The present chapter reports the results of the production tasks administered to the participants for this study, details the methods used to analyze the data generated from these tasks, and provides a discussion of these analyses with regards to this study's guiding questions and hypotheses. The English production task (see Appendix D) was carried out with all three groups (i.e., the intermediate and advanced proficiency L2 experimental groups and the native speaker control group) and the BP production task (see Appendix E) was carried out with the two experimental groups.

This chapter will be organized as follows: First, I review the research questions and hypotheses pertaining to vowel production that guide this study. Second, the motivation for and an explanation of vowel normalization procedures are provided. Third, I present the results of the production tests for each of the three groups. Finally, an analysis and discussion of these data are provided.

4.1 Production Research Questions and Hypotheses

The present study is concerned with the acquisition of English vowels by native speakers of BP, with "acquisition" being defined as the participants' ability to both accurately produce and perceive these vowels. With this in mind, this study is guided by the following research question regarding the production of the English vowels:

1. Concerning production of CE vowels, how will the experimental groups' productions–as measured in terms of formant frequencies, vowel durations, and Euclidean distances between vowel pairs–of the English L2 vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o,

ʊ, u/) differ between the intermediate and advanced learner experimental groups and the native English speaker control group? How will the participants' productions of the L2 vowels compare to their productions of the L1 BP vowels (/i, e, ɛ, a, ɔ, o, u/)?

From these research questions, the theoretical framework of the SLM (Flege, 1995; Flege, 2005), and the findings of previous studies (e.g., Bion et al., 2006; Rauber, 2006) the following hypotheses pertaining to production were developed:

A. L2 (CE) vowels that are *similar* to L1 (BP) vowels (i.e., those that occur in both inventories, but have different acoustic properties; /i, e, ɛ, u, o/) will be produced with formant values similar to the BP vowels in the intermediate group and in the advanced group they will be an intermediary between the BP and CE L1 vowels.

B. L2 (CE) vowels that are *new* (i.e., those that do not occur in the BP inventory; /ɪ, æ, ʊ, ʌ, ɑ/) will be produced with formant values similar to native speaker formant values in the advanced group and will not be acquired in the intermediate group.

C. New vowels that are too similar to an existing phonetic category will remain persistently difficult to acquire across the proficiency groups, with the existing L1 sound and new L2 sound eventually merging into an intermediary form rather than a new contrast being formed.

In order to test these hypotheses, two production tasks were administered: an English reading task and a BP reading task. The first task was completed by all of the participants, while the second was only completed by the experimental participants. In the English reading task, participants were asked to read a list of sentences (see Appendix D)—adapted from Rauber (2006)—that acted as carriers for 60 words, including some nonce words, containing six tokens for each of the ten vowels of CE (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/). In the BP reading task, participants were asked to read a list of sentences in BP (see Appendix E)–also adapted from Rauber (2006). These sentences contained 70 words and nonce words containing ten tokens for each of the seven vowels of BP (/i, e, ɛ, a, ɔ, o, u/).

After these data were collected, the first and second formant (F1 and F2) values of each vowel token, as well as the duration, were measured. These formant values were then normalized; both within groups (e.g., all intermediate L2 formant values) and between groups (e.g., the intermediate L2 and the control groups, the advanced L2 and the control group, etc.) in order to account for differences between individuals and produce comparable vowel spaces (see Section 4.2). The mean, median, and standard deviation for the F1, F2, and duration of each vowel token were then calculated for each group and each vowel inventory. The mean formant values were then charted on a scatter plot in order to show their position within the participants' vowel space. Additionally, the ED between the CE vowel pairs was measured and statistical analyses were run on the data, the details of which are described in the following sections.

4.2 Vowel Normalization Procedures

The current chapter provides the results of the production task in form of acoustic measurements, as well as a comparison between the groups. In order to account for the differences in vocal tract length, gender, age, and other variables that can affect acoustic output, the formant data were normalized. This normalization process results in comparable vowel spaces between the groups, as well as means of accounting for variation within groups when calculating mean formant values.

The data were normalized using the NORM Vowel Normalization and Plotting Suite (Thomas & Kendall, 2007). After loading the unnormalized data values, they were normalized using the Watt and Fabricius method of vowel normalization (Watt & Fabricius, 2002). In this method, the vowels are normalized by using "point vowels" in the data set that represent the top left, top right, and bottom corners of the vowel space. The process begins by first calculating *S transforms* for F1 and F2. The *S transforms* for F1 and F2 are calculated using the vowel in the data set with the minimum F1 and maximum F2 to represent the top left corner of the vowel triangle (i.e., typically an /i/ token; see Figure 8 for a representation of the vowel triangle), the vowel with the maximum F1 value to represent the bottom corner (which I call /a/ in our formula, but may be /æ/, /ɑ/, or /a/ depending on the group), and the vowel with the minimum F1 and F2 to represent the top rear corner of the vowel triangle (i.e., typically an /u/ token). The formant values from these "point" vowels are then summed and divided by 3 to find the respective *S transforms* for F1 and F2 (cf. formulas 2 and 3).

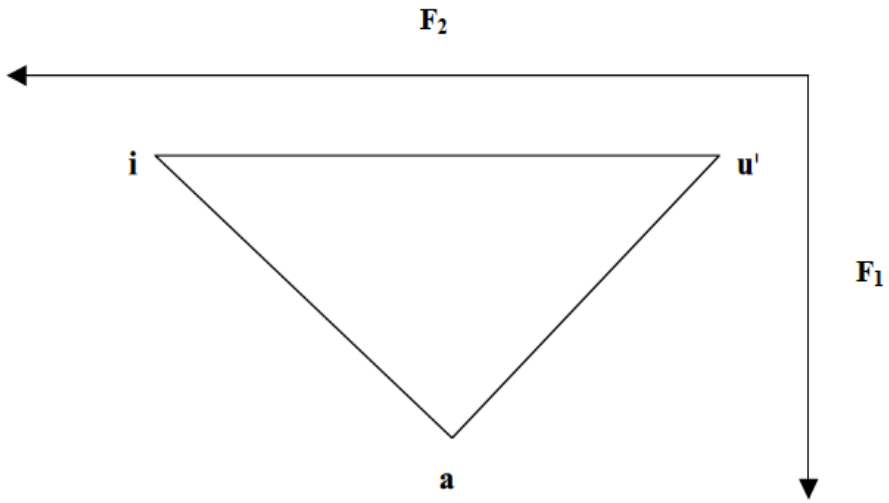

Figure 8. Schematized representation of the vowel triangle used in the vowel normalization process. Reprinted from Watt and Fabricius (2002).

The F1 and F2 for each vowel in the data set are then divided by their respective *S transform* resulting in normalized values called *S values*.

$$S(F1)=(i_{F1} + æ_{F1} + u_{F1})/3 \quad (2)$$

$$S(F2)=(i_{F2} + æ_{F2} + u_{F2})/3 \quad (3)$$

Finally, after the vowels have been normalized resulting in *S Values* these values are scaled back to the Hertz scale in order to provide data in a more familiar unit of measurement. This rescaling process is performed using all of the normalized data at once, in order to prevent any adverse effects[6] that may occur when group or individual data are rescaled separately. The formulas used for the scaling algorithm are provided below in (4) and (5) (Thomas & Kendall, 2007).[7]

[6] According to Thomas and Kendall (2007), rescaling by group can undo the normalization by scaling each vowel to its relative position in each group's vowel space, rather than across groups.

[7] In formulas (4) and (5), F^N_i is a normalized value for formant i, while F^N_{1MIN} and F^N_{1MAX} are the minimum and maximum normalized values for that formant.

$$F1 = 250+500\ (F^{N}_{1} - F^{N}_{1MIN}) / (F^{N}_{1MAX} - F^{N}_{1MIN}) \quad (4)$$

$$F2 = 850+1400\ (F^{N}_{2} - F^{N}_{2MIN}) / (F^{N}_{2MAX} - F^{N}_{2MIN}) \quad (5)$$

4.3 Production Results

4.3.1 Control participants. The L1 CE speaking control participants completed only the English reading task for this study. Because they are used as a means of comparison with the experimental groups, it is perhaps appropriate to present their data first in order to provide a baseline for the CE vowels.

The production task resulted in a total of 360 vowel tokens for the control group (6 tokens per vowel X 10 vowels X 6 participants). The F1, F2, and duration were measured from these tokens as described in Section 3.5.2 and the raw formant values were then normalized using the process described above in Section 4.2. Table 13 below provides the mean (*M*), median (*Md)*, and standard deviation (*SD*) of the duration (measured in milliseconds), and the F1 and F2 (measured in Hertz) of all the vowels produced by the control participants.

Table 13. Mean, Median, and Standard Deviation (SD) of Duration (D), F1, and F2 Values of CE Vowels Produced by Control Participants. Number of tokens = 360 (6 tokens X 10 vowels X 6 participants).

		/i/	/ɪ/	/e/	/ɛ/	/æ/	/ʌ/	/ɑ/	/o/	/ʊ/	/u/
	N	36	36	36	36	36	36	36	36	36	36
	Mean	128	108	151	118	163	119	164	146	113	134
D	Med.	119	106	151	114	106	118	157	138	110	133
(ms)	SD	31	31	35	33	34	29	37	30	32	34
	Mean	292	434	396	575	672	594	620	458	468	330
F1	Med.	291	431	404	570	684	588	625	454	465	329
(Hz)	SD	18	30	35	41	50	55	27	39	35	29
	Mean	1990	1674	1873	1498	1450	1298	1044	1079	1243	1471
F2	Med.	2020	1688	1866	1518	1468	1302	1051	1085	1244	1472
(Hz)	SD	176	74	113	113	92	86	61	108	80	181

The mean formant values for these vowels were then charted on a scatter plot in order to map the general vowel space of the L1 CE participants (see Figure 9). The resulting plot displays a vowel space typical of CE, as described in Section 2.2.2.2. To wit, the vowels /ʌ/ and /ʊ/ are centralized in the vowel space and occur in front of the open back vowel /ɑ/. /u/ is also centralized and produced in the middle of the vowel space. The vowels /ɛ/ and /ɪ/ are retracted towards the center of the vowel space. /æ/ is lowered and occurs as the most open vowel in the system, which is a designation that would be given to /ɑ/ in General American (cf. Figure 4, Section 2.2.2.2). These characteristics are consistent with the Canadian Shift as described by others (Hagiwara, 2006; Labov et al., 2006). In other words, the control group seems to speak a variety of CE that is standard for the region.

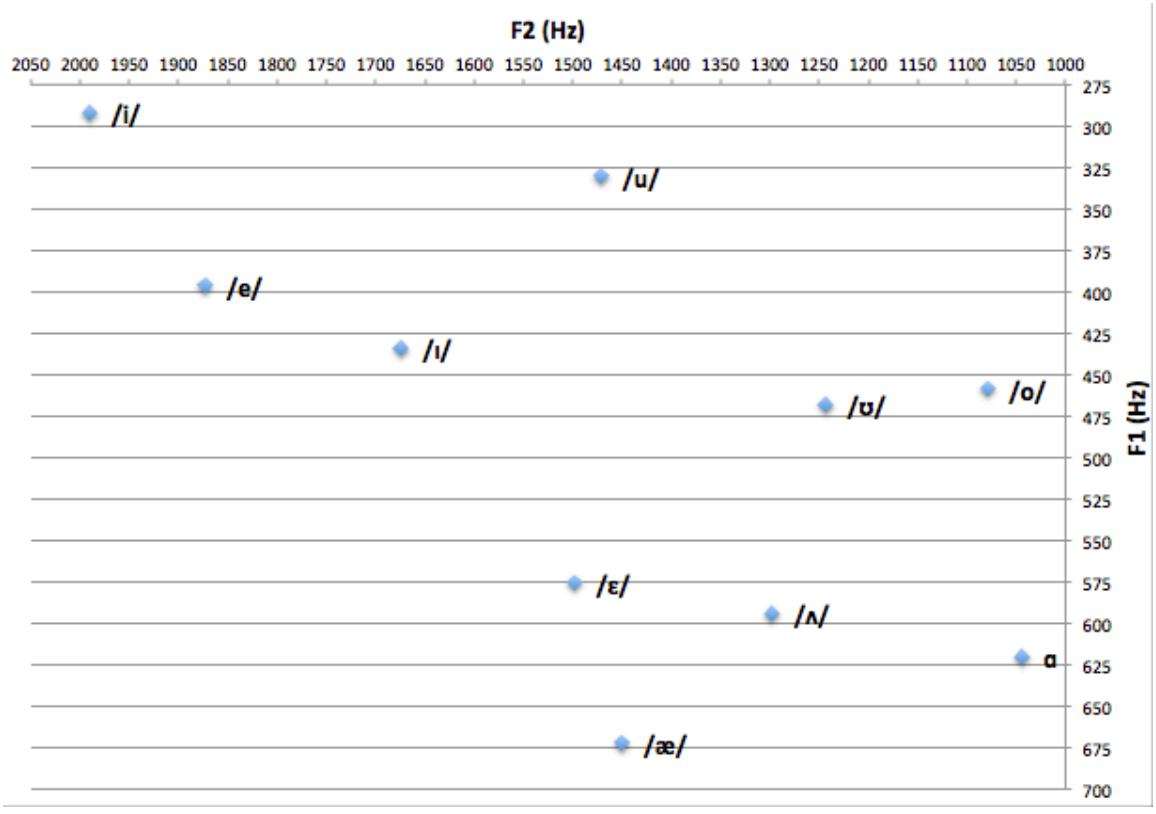

Figure 9. Scatter plot displaying the mean formant values of the control group's CE vowels.

Finally, the ED of ten CE vowel pairs (/i/-/ɪ/, /ɪ/-/e/, /e/-/ɛ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/o/, /o/-/ɑ/ /ʊ/-/ʌ/, /ʌ/-/ɑ/, and /ʌ/-/æ/) were calculated from the data (using Formula 1, cf. Section 3.5.2). The mean, median, and standard deviation of these distances–organized from the shortest to greatest distance–is presented in Table 14. It should be noted that these distances will be used as a means of comparison with the L2 groups, and so the data was normalized between groups, rather than just between the speakers of the control group.

Table 14. Mean, Median, and Standard Deviation (SD) of the Euclidean Distances, in Hertz, between the CE Vowel Pairs as Produced by the Control Participants, Organized from Least to Greatest Distance.

	/ɛ/-/æ/	**/ʊ/-/ʌ/**	**/ʊ/-/o/**	**/ʌ/-/æ/**	**/ɪ/-/e/**
Mean	109	139	142	163	175
Median	102	133	144	157	165
SD	29	36	61	51	76
	/o/-/ ɑ /	**/ʌ/-/ɑ/**	**/u/-/ʊ/**	**/i/-/ɪ/**	**/e/-/ɛ/**
Mean	179	225	242	307	372
Median	170	223	202	309	361
SD	29	29	81	42	125

4.3.2 Intermediate English proficiency participants. The intermediate proficiency group completed both the English reading task and the BP reading task. The resulting formant values measured from these data were normalized together (§ Section 4.2). The English production task resulted in a total of 480 vowel tokens for the intermediate group (10 CE vowels X 6 tokens per vowel X 8 participants). The mean, median, and SD of all the L2 CE vowels produced by the intermediate proficiency level participants are displayed in Table 15. Additionally, the raw formant values were normalized with those of the control and advanced L2 groups and the EDs between the

ten CE vowel pairs were calculated. Table 16 displays the mean, median, and standard deviation of these distances.

Table 15. Mean, Median, and Standard Deviation (SD) of Duration (D), F1, and F2 Values of CE Vowels Produced by Intermediate Proficiency L2 Participants. *N* = 480 (6 tokens X 10 vowels x 8 participants).

		/i/	/ɪ/	/e/	/ɛ/	/æ/	/ʌ/	/ɑ/	/o/	/ʊ/	/u/
	N	48	48	48	48	48	48	48	48	48	48
	Mean	109	110	161	144	163	126	146	157	122	120
D	Med.	106	102	159	142	158	130	153	155	120	117
(ms)	SD	35	43	49	44	54	35	40	41	39	40
	Mean	317	320	382	551	564	440	573	417	382	359
F1	Med.	311	320	386	542	566	438	571	413	391	348
(Hz)	SD	24	21	36	59	61	58	46	39	47	39
	Mean	1980	1981	1900	1689	1697	1450	1193	1123	1238	1268
F2	Med.	1974	1973	1899	1709	1722	1473	1184	1105	1205	1260
(Hz)	SD	84	94	94	66	99	148	74	95	156	222

Table 16. Mean, Median, and Standard Deviation (SD) of the Euclidean Distance, in Hertz, between the CE Vowel Pairs as Produced by Intermediate L2 Participants, Organized from Least to Greatest Distance

	/i/-/ɪ/	/ɛ/-/æ/[8]	/ɪ/-/e/	/ʊ/-/o/	/u/-/ʊ/
Mean	30	36	117	146	161
Median	26	26	99	122	121
SD	21	25	52	75	107
	/o/-/ ɑ /	/ʊ/-/ʌ/	/e/-/ɛ/	/ʌ/-/æ/	/ʌ/-/ɑ/
Mean	189	241	290	307	321
Median	186	215	257	278	297
SD	54	100	84	107	99

[8] Participant IF2's data was not used to calculate the mean and median ED for the /ɛ/-/æ/ as it was several standard deviations from the mean.

The BP production task resulted in a total of 560 vowel tokens for the intermediate group (7 BP vowels X 10 tokens per vowel X 8 participants). The mean, median, and standard deviation of the F1, F2, and duration from these BP vowels are displayed in Table 17.

Table 17. Mean, Median, and Standard Deviation (SD) of Duration (D), F1, and F2 Values of BP Vowels Produced by Intermediate Proficiency L2 Participants. *N* = 560 (10 tokens X 7 vowels x 8 participants).

		/i/	/e/	/ɛ/	/a/	/ɔ/	/o/	/u/
	N	80	80	80	80	80	80	80
	Mean	105	129	144	142	136	130	112
D	Med.	103	131	144	141	136	131	114
(ms)	SD	27	33	27	27	30	33	25
	Mean	294	376	483	670	509	410	348
F1	Med.	294	351	488	670	521	384	328
(Hz)	SD	20	74	67	41	71	73	61
	Mean	1989	1869	1759	1423	1119	1077	1176
F2	Med.	1984	1882	1749	1420	1119	1077	1067
(Hz)	SD	87	78	81	75	72	91	339

Finally, the mean formant values for the intermediate group's CE and BP vowels were then charted together on a scatter plot (see Figure 10) in order to show the general shape of the intermediate L2 group's vowel space with regards to both CE and BP. It is readily apparent from both Figure 10 and the above tables that the intermediate speakers drew little to no distinction between several CE vowel pairs, namely /i/-/ɪ/, /ɛ/-/æ/, and /u/-/ʊ/. The intermediate group did not appear to use duration as a cue in producing these vowel contrasts for the most part. The /i/-/ɪ/ and /u/-/ʊ/ pairs' mean durations only differed by 1-2 milliseconds. While the control group's mean duration for /æ/ was 19 milliseconds longer than for /ɛ/, this still falls quite short of the control group who

produced a mean difference of 45 milliseconds between the vowels. Furthermore, the intermediate group produced the CE vowels /i/, /e/, /u/, /o/ with formant values similar to their BP counterparts. In other words, a preliminary visual analysis of the data appears to confirm the hypotheses related to production for the most part. However, an in-depth analysis is provided in Section 4.4.

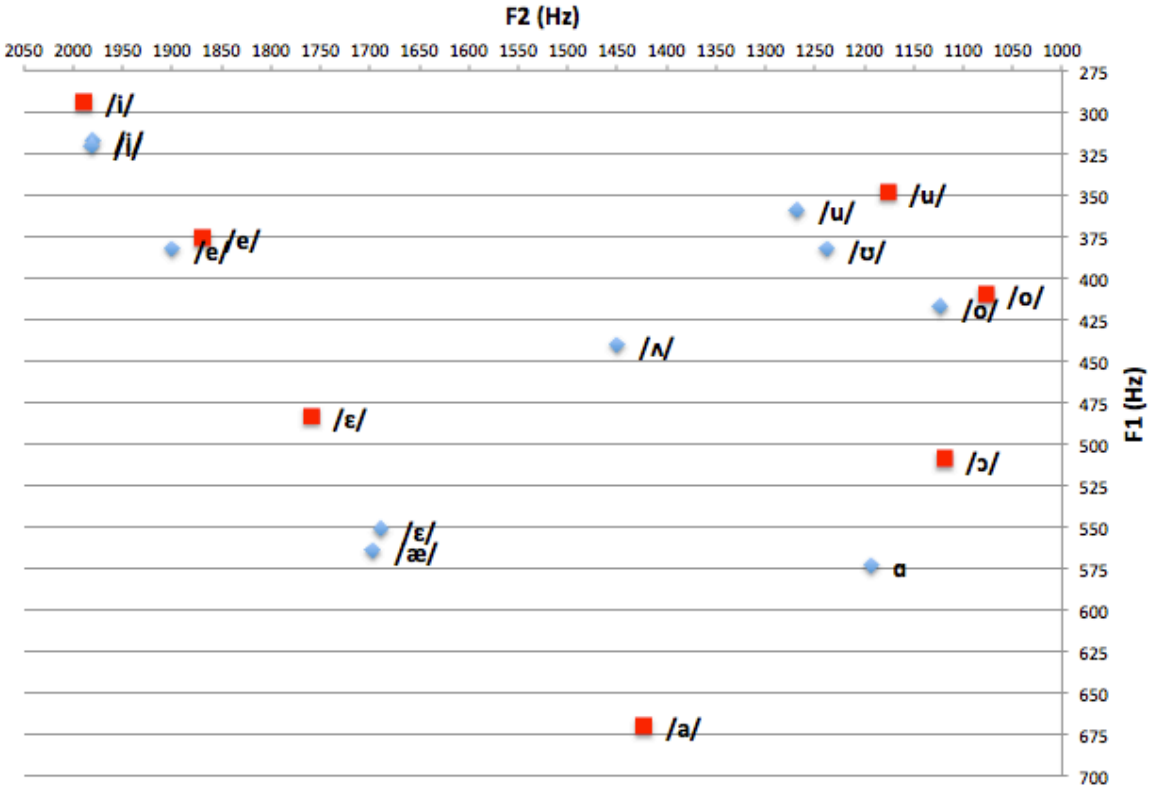

Figure 10. Scatter plot displaying the mean formant values of the intermediate proficiency group's L2 vowels (blue diamonds) and BP vowels (red squares).

4.3.3 Advanced English proficiency participants. The advanced proficiency group completed both the English reading task and the BP reading task. The English reading task resulted in a total of 360 vowel tokens for the advanced group (6 tokens per vowel X 10 vowels X 6 participants). The resulting formant values measured from these data were normalized together (§ Section 4.2). The mean, median, and standard deviation

of all and the mean, median, and standard deviation of the duration, F1, and F2 of all the L2 CE vowels produced by the advanced proficiency level participants are displayed in Table 18. The EDs between the ten CE vowel pairs were calculated for the advanced L2 group as described and the group mean, median, and standard deviation were calculated for each pair (§ Table 19).

Table 18. Mean, Median, and Standard Deviations (SD) of Duration (D), F1, and F2 Values of CE Vowels Produced by Advanced Proficiency L2 Participants. *N* = 360 (6 tokens X 10 vowels X 6 participants).[9]

		/i/	/ɪ/	/e/	/ɛ/	/æ/	/ʌ/	/ɑ/	/o/	/ʊ/	/u/
	N	36	36	36	36	36	36	36	36	36	36
	Mean	138	115	167	147	170	125	165	169	126	146
D	Med.	129	107	171	136	167	118	159	157	122	132
(ms)	SD	40	31	50	43	45	38	43	42	39	42
	Mean	318	395	401	588	606	509	580	441	397	354
F1	Med.	314	398	401	581	594	506	594	442	401	362
(Hz)	SD	32	52	28	35	48	58	44	26	65	34
	Mean	2062	1914	1926	1664	1641	1514	1245	1204	1379	1431
F2	Med.	2070	1943	1936	1663	1599	1548	1235	1197	1381	1422
(Hz)	SD	94	115	130	141	119	94	78	105	190	223

Table 19. Mean, Median, and Standard Deviation (SD) of the Euclidean Distances, in Hertz, between the CE Vowel Pairs as Produced by Advanced L2 Participants, Organized from Least to Greatest Distance

	/ɛ/-/æ/	/u/-/ʊ/	/ɪ/-/e/	/o/-/ ɑ /	/i/-/ɪ/
Mean	45	120	118	178	185
Median	39	97	118	177	150
SD	31	89	64	42	103
	/ʌ/-/æ/	/ʊ/-/o/	/ʊ/-/ʌ/	/ʌ/-/ɑ/	/e/-/ɛ/
Mean	193	211	242	305	349
Median	192	145	237	300	374
SD	63	146	127	70	63

[9] While the mean and median formant values provided here are very telling, it should be noted that there was a considerable amount of variation amongst individuals, with some participants (i.e., AM3) producing vowels that were closer to native speaker values.

The BP production task resulted in a total of 420 vowel tokens for the advanced L2 group (7 BP vowels X 10 tokens per vowel X 6 participants). The mean, median, and standard deviation of the F1, F2, and duration from these BP vowels are displayed in Table 20.

Table 20. Mean, Median, and Standard Deviation (SD) of Duration (D), F1, and F2 Values of BP Vowels Produced by Advanced Proficiency L2 Participants. *N* = 420 (10 tokens X 7 vowels X 6 participants).

		/i/	/e/	/ɛ/	/a/	/ɔ/	/o/	/u/
	N	60	60	60	60	60	60	60
	Mean	110	144	146	155	158	134	109
D.	Med.	109	133	146	152	159	129	113
(ms)	SD	25	57	33	33	33	37	29
	Mean	328	395	523	661	543	435	360
F1	Med.	316	389	535	659	547	430	363
(Hz)	SD	42	48	48	30	28	42	31
	Mean	2015	1852	1764	1423	1202	1176	1153
F2	Med.	2015	1873	1764	1423	1208	1111	1084
(Hz)	SD	104	145	88	82	54	232	228

Finally, the mean formant values for the advanced group's CE and BP vowels were then charted together on a scatter plot (see Figure 11). While an in-depth analysis of these data will follow, it may be observed from Figure 11–as well as Tables 18-20–that the vowel space of the advanced participants displayed evidence of a greater acquisition of the CE vowels than the intermediate group. The distances between vowels in the pairs /i/-/ɪ/ and /u/-/ʊ/ were noticeably greater than in the intermediate group, and there is evidence that some similar vowels are produced with formant levels more characteristic of CE (e.g., L2 /u/ was visibly fronted in the advanced speakers' vowel space). However,

the vowel contrast /ɛ/-/æ/ appeared to remain persistently difficult to produce and, unexpectedly, there appeared to be little distinction between the vowels /ɪ/ and /e/. At first glance, it appeared that the advanced group may perceive the difference between these two vowels as being one of length, as the mean duration of /e/ was 19 milliseconds longer than that of /ɪ/. Furthermore, /e/ is a tense vowel, while /ɪ/ is lax. However, the advanced group did not appear to have used duration as a cue for producing other contrasts (e.g., /ɛ/ and /æ/, whose mean durations only differed by 2 milliseconds).

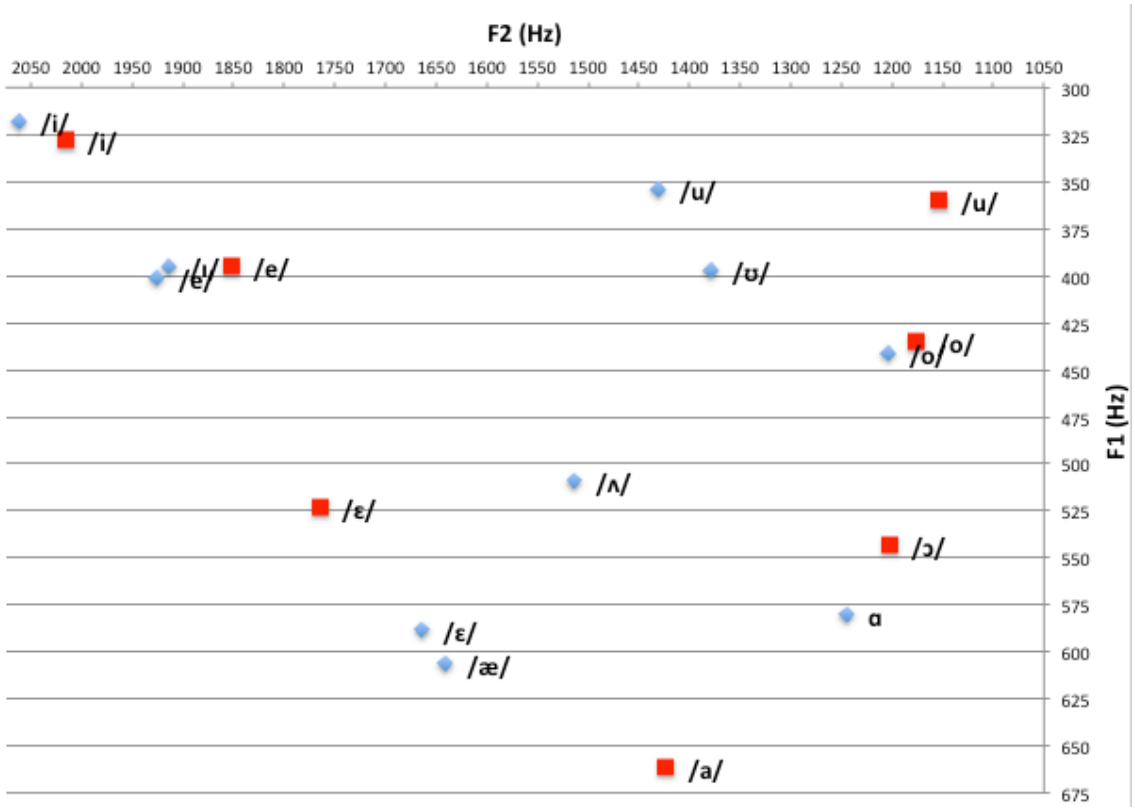

Figure 11. Scatter plot displaying the mean formant values of the advanced proficiency group's L2 vowels (blue diamonds) and BP vowels (red squares).

4.4 Production Analysis

In the following section, a more in-depth analysis of the data generated from the production tasks is presented. The analysis is organized into two parts: one section for the

intermediate L2 learners and another for advanced L2 learners. Each of these sections seeks to confirm or reject the hypotheses posed above and in Section 3.1, thereby working towards answering the research questions posed by this study.

4.4.1 Intermediate English proficiency participants. The research questions of this study pertaining to production ask, in essence, how each experimental group's L2 vowels will compare to those of the control group, as well as to their L1. With that in mind, the raw data generated from the production tasks for the control and intermediate groups were normalized together. Then, the BP, CE L2 (i.e., the intermediate group's productions), and CE L1 (i.e., the control group's productions) were plotted together in order to provide a direct means of comparison between the two groups (see Figure 12).

A visual analysis of the resultant vowel plot revealed much regarding the intermediate group and how it differs from the control group. Speaking in relative terms, it is apparent that some L2 vowels–namely /i/ and /e/–were produced with formant values similar to those of the control group. However, it should be noted that these were possibly only being produced accurately by virtue of their being close to preexisting phonetic categories (i.e., BP /i/ and /e/). Meanwhile, the remaining L2 vowels (/ɪ, ɛ, æ, ʌ, u, ʊ, o, ɑ/) were produced *inaccurately*, in that they are relatively distant from those of the control group.

In addition to /i/ and /e/, it may be observed that of the remaining *similar* vowels /o/ and /u/ were produced with formant levels similar to those of their BP counterparts, while /ɛ/ appears to have been produced as more open than its BP counterpart and more fronted than the control group production. In the case of *new* vowels, /ɪ, æ, ʊ/ appear to have been assimilated to the nearest existing phonetic categories, which would be /i/, /ɛ/, and /u/,

respectively. Meanwhile, /ʌ/ was produced significantly more closed than in the control group; occurring somewhere near the middle of the vowel space.

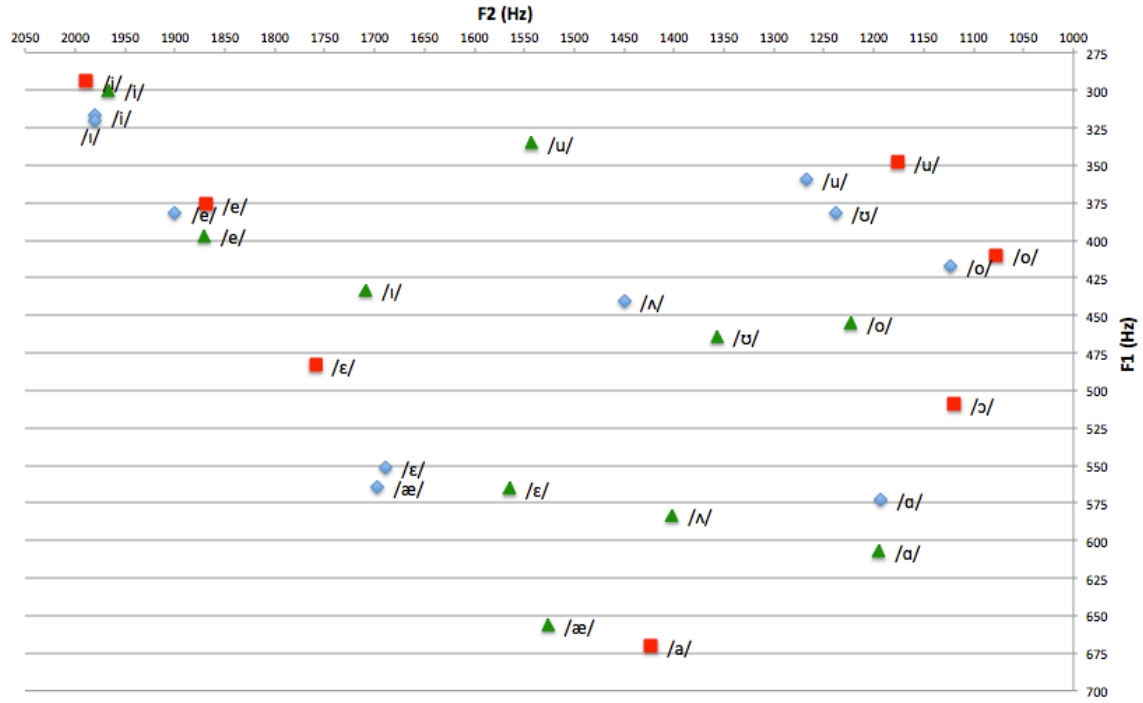

Figure 12. Scatter plot displaying the mean formant values of the intermediate proficiency group's L2 vowels (blue diamonds) and BP vowels (red squares) and the control group's L1 vowels (green triangles).

Finally, /ɑ/ appears to be produced *relatively* closely to the control group, but could be viewed as something of an intermediary between the L1 /ɑ/ and its closest counterpart in the BP system (the open back rounded vowel /ɔ/).

While these observations serve to paint a picture of the intermediate group's vowel productions in regards to this study's guiding questions, it is important to note that the mean formant values paint an incomplete picture at best, and it is nevertheless necessary to approach these questions in terms of the hypotheses generated from these questions.

4.4.1.1 Hypothesis A. Hypothesis A, in regards to the intermediate group, postulates that the CE vowels that are similar to L1 BP vowels (/i, e, ɛ, u, o/) will be produced with

formant values similar to the BP vowels. Therefore, the hypothesis suggests that the similar L2 CE vowels will be closer to their BP counterparts than to the CE vowels of the control group (i.e., the target language, henceforth TL). With that in mind, the ED was calculated between each intermediate participant's mean productions of L2 /i, e, ɛ, u, o/ and their mean productions of BP /i, e, ɛ, u, o/, as well as between their L2 production and the control group's mean productions of these vowels in order to see whether the intermediate participants produced an L2 vowel that was closer to BP or to the control group's CE vowels. The mean, median, and standard deviations of these distances are displayed in Table 21.

Table 21. Euclidean Distance in Hertz Between (A) the Intermediate Participants' L2 Vowels and (B) BP Vowels and Between (A) the L2 Vowels and (C) Control L1 Vowels

L2	Distance to:	BP	Control
	Mean	54	59
/i/	Median	50	58
	SD	29	34
	Mean	75	59
/e/	Median	64	47
	SD	51	28
	Mean	103	140
/ɛ/	Median	86	137
	SD	65	37
	Mean	238	307
/u/	Median	156	288
	SD	202	116
	Mean	62	111
/o/	Median	48	111
	SD	31	44

The intermediate group's L2 vowel /i/ occured closer to its BP counterpart than to the TL /i/, although the difference between the two distances is slight (i.e., the mean ED between the

L2 and BP is only 5 Hz closer than the L2 and the TL). However, as can be observed in the production results, BP /i/, L2 /i/, and TL /i/ differ only slightly phonetically.

/e/, unlike the other similar L2 vowels, appears to be closer to the TL /e/ than to BP /e/, which goes against the hypothesis. While there is a considerable amount of variation amongst the participants, the distances presented above appear to accurately reflect the data with only three of the intermediate participants (i.e. IF1, IF5, and IM1) producing an L2 /e/ that is closer to BP than to the TL. However, like /i/, the BP, L2, and TL productions of /e/ do not appear to vary much phonetically, and it is therefore difficult to confirm or reject the hypothesis.

The remaining similar vowels–L2 /u, o, ɛ/–occurred much closer to their BP counterparts than to the TL vowels. L2 /u/ occurred on average 168 Hz closer to its BP counterpart than to the TL /u/. As can be observed in Figure 12, the L2 production occurs towards the back of the vowel space near BP /u/, while the TL /u/ is centralized. L2 /o/ was an average of 49 Hz closer to its BP counterpart, which is more close and back than the TL /o/. Finally, L2 /ɛ/ was an average of 37 Hz closer to its BP counterpart than to the TL vowel. However, Figure 12 indicates that L2 /ɛ/ occurred at an intermediary point between BP and TL /ɛ/. While a more in-depth discussion of the vowel pairs follows below, a possible explanation could be that the participants produce an L2 /ɛ/ that is generally more open than BP /ɛ/ because they are producing /ɛ/ and /æ/ as the same vowel.

4.4.1.2 Hypotheses B and C. This study's second hypothesis, as it pertains to the intermediate group, states that the L2 vowels that are new (i.e., not occurring in the BP inventory; /ɪ, æ, ʊ, ʌ, ɑ/) will not have been acquired yet. The third hypothesis–Hypothesis C–pertaining to production is similar to the second in that it postulates that new vowels that

are too similar to an existing phonetic category will remain persistently difficult to acquire across the proficiency groups, and predicts that the new L2 sound and the closest preexisting L1 sound will eventually merge into an intermediary form. This acquisition is viewed in terms of the of the participants' ability to not only produce vowels that are phonetically similar to their TL counterparts, but also to display a contrast between various vowel pairs. In Figure 12, it is apparent that the intermediate participants fail to make a distinction between the pairs /i/-/ɪ/ and /ɛ/-/æ/, and to a lesser degree /u/-/ʊ/. If the participants have acquired a vowel, the distance between it and the other vowels in their vowel space is expected to be similar to the distances exhibited by the control group.

With this in mind, statistical tests were carried out in order to compare the EDs between the intermediate group and the control group's productions of ten CE vowel pairs: /i/-/ɪ/, /ɪ/-/e/, /e/-/ɛ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/o/, /o/-/ɑ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, and /ʌ/-/æ/. Levene's test showed an unequal variance between the intermediate and control groups ($F = 6.23$, $p = .014$), so Welch's *t*-test was used. The mean EDs of the vowel pairs for the control group and the intermediate group, the similarity between the two groups (calculated by dividing the smaller ED by the greater), and the results of the *t*-test comparing the two groups are displayed below in Table 22.

As can be observed from Table 22, the ED's for five of the intermediate group's CE vowel pairs were significantly different than the control group: /i/-/ɪ/, /ɛ/-/æ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, /ʌ/-/æ/, which supports the hypothesis that the new vowels (/ɪ, æ, ʊ, ʌ, ɑ/) will not be acquired in the intermediate group.

Table 22. Mean Values of the Euclidean Distances Between the CE Vowel Pairs for the Control and Intermediate Participants, Percentage of L1 vs. L2 Similarity, and *t*-tests

Vowel Pair	Control (Hz)	L2 (Hz)	L1 vs. L2 Similarity	*t*-test
/i/-/ɪ/	307	30	9.7%	$t(7) = -14.9$, $p < .0001$
/ɪ/-/e/	175	117	66.9%	$t(8) = -1.62$, $p = .14$
/e/-/ɛ/	372	290	77.9%	$t(8) = -1.39$, $p = .2$
/ɛ/-/æ/	109	36	33%	$t(10) = -4.77$, $p = .0007$
/u/-/ʊ/	242	161	66.5%	$t(12) = -1.6$, $p = 0.13$
/ʊ/-/o/	142	146	97.3%	$t(12) = .13$, $p = .9$
/o/-/ɑ/	179	189	94.7%	$t(11) = .45$. $p = .66$
/ʊ/-/ʌ/	241	139	57.7%	$t(9) = 2.66$, $p = .0255$
/ʌ/-/ɑ/	225	321	70%	$t(9) = 2.59$, $p = .0303$
/ʌ/-/æ/	163	307	53%	$t(11) = 3.32$, $p = .00725$

Regarding the vowel /ɪ/, the intermediate participants showed a clear inability to contrast this vowel with its tense counterpart /i/. An independent sample *t*-test showed that the distance between /i/ and /ɪ/ for the intermediate group was significantly less than the control ($t(7) = -14.9$, $p < .0001$) and that there was only a 9.7% similarity between the two groups. Furthermore–as displayed in Table 15–the mean formant values for the two vowels are nearly identical, with the F1s and F2s showing a 99% and 99.9% similarity, respectively.

The intermediate participants showed a similar inability to produce the new vowel /æ/. This is especially apparent with regards to the /ɛ/-/æ/ vowel contrast, with the mean ED between the vowels only being 33% of the ED displayed be the control group and differing significantly ($t(10) = -4.77$, $p = .0007$). /æ/ appears to have assimilated to the closest preexisting phonetic category /ɛ/, with the mean F1 and F2 values having a 97.7% and 85.4% similarity to the F1 and F2 of /ɛ/.

While the results of the *t*-test for the tense-lax vowel pair /u/-/ʊ/ showed an insignificant difference between the EDs of the intermediate and control group ($t(12) = -1.6$, $p = 0.13$) a reassessment of the data indicates that the vowel /ʊ/ is likely assimilated to the preexisting category for BP /u/. Figure 13, which displays all L2 vowel tokens produced by the intermediate group, shows that the vowels /u/ and /ʊ/ displayed a high degree of variability, especially with regards to their frontness. The mean F2 of /u/ was 1268 Hz with a standard deviation of 222 Hz, and the mean F2 of /ʊ/ was 1238 Hz with a standard deviation of 156 Hz. As a result, the ED of the /u/-/ʊ/ contrast showed a similar degree of variability ($M = 161$ Hz, $SD = 107$). However, a visual representation of the tokens in Figure 13 indicates a high degree of overlap between /u/ and /ʊ/.

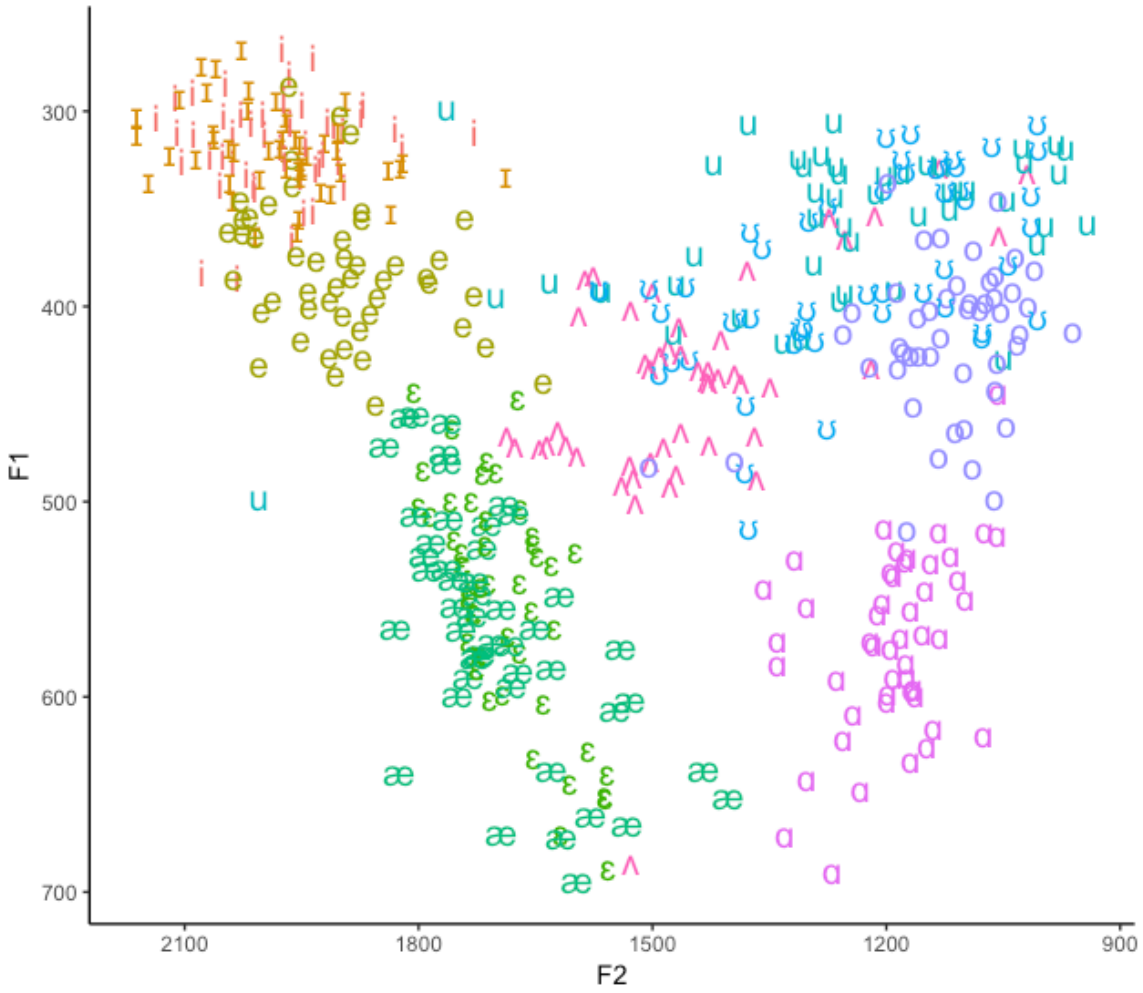

Figure 13. Scatter plot of all L2 vowel tokens produced by the intermediate proficiency group.

The L2 vowel /ʌ/ also showed a relatively high level of variability. This is especially apparent in its frontness, with the mean F2 having a mean of 1450 Hz and an standard deviation of 148 Hz. With regards to the *t*-tests of the vowel pairs, all three vowel pairs containing /ʌ/ were shown to have an ED that differed significantly from the control group: /ʊ/-/ʌ/ ($t(9) = 2.66$, $p = .0255$), /ʌ/-/ɑ/ ($t(9) = 2.59$, $p = .0303$), /ʌ/-/æ/ ($t(11) = 3.32$, $p = .00725$). A visual analysis of Figure 13–as well as Figure 12–show that /ʌ/ occupies a central location in the L2 vowel space, as opposed to the more open position of L1 /ʌ/.

As stated in Section 4.4.1, the intermediate participants appear to have established a phonetic category for the L2 vowel /ɑ/, contrary to Hypothesis B. However, as evidenced by Figure 12, it appears to be an intermediary form between the L1 open mid-back rounded vowel /ɔ/ and L2 /ɑ/. Figure 13 indicates that the majority of the /ɑ/ tokens ranged in height between roughly 500 and 600 Hz, which covers the distance between the mean F1 of L1 /ɔ/ (509 Hz) and the mean F1 of L1 /ɑ/ (620 Hz). The results of the *t*-tests are somewhat inconclusive, with a comparison of the /o/-/ɑ/ ($t(11) = .45$. $p = .66$) pair not showing a significant difference between the intermediate and control groups, while a comparison of the /ʌ/-/ɑ/ pair did ($t(9) = 2.59$, $p = .0303$).

4.4.2 Advanced English proficiency participants. Like the intermediate group, the advanced group's production data were normalized with that of the control group. Then, the BP, CE L2 (i.e., the advanced group's productions), and CE L1 (i.e., the control group's productions) were plotted together in order to provide a direct means of comparison between the two groups (see Figure 14).

A visual analysis of the vowel plot shows that while some of the L2 vowels of the advanced speakers showed a closer resemblance to the TL vowels of the control, there still remains room for improvement. Like the intermediate proficiency group, the advanced speakers' mean productions of the L2 vowels /i/ and /e/ occurred relatively close to the mean productions of the control group.

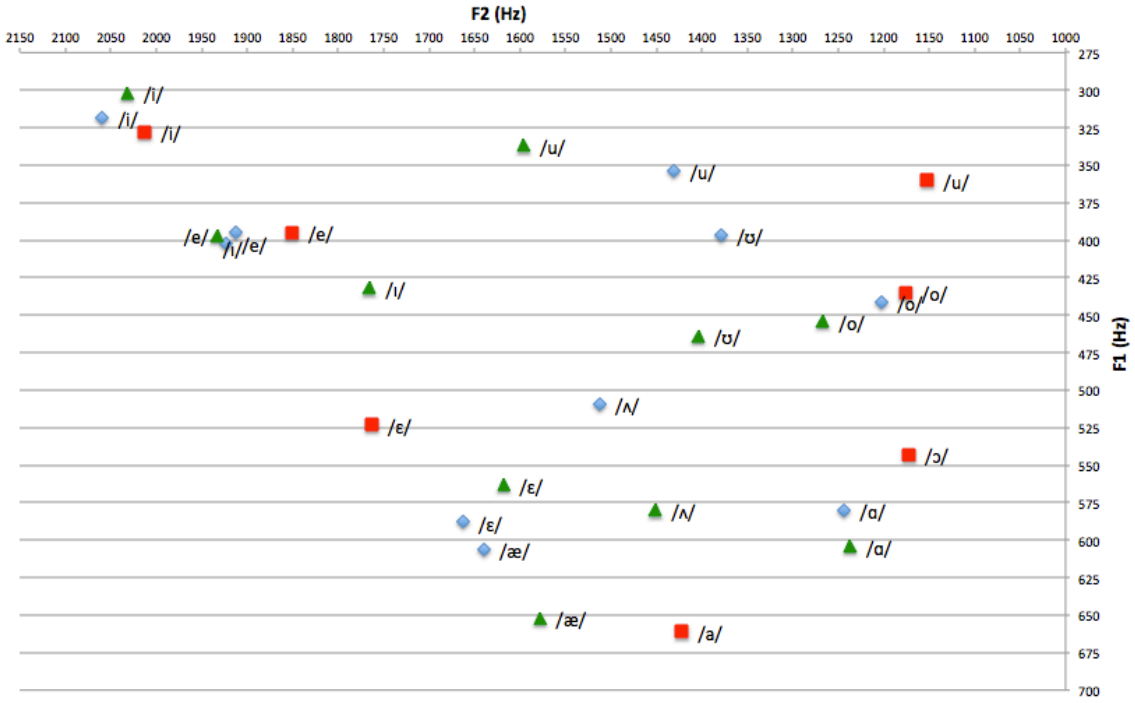

Figure 14. Scatter plot displaying the mean formant values of the advanced proficiency group's L2 vowels (blue diamonds) and BP vowels (red squares) and the control group's L1 vowels (green triangles).

The L2 vowel /ɛ/ appears to have been produced much closer to that TL /ɛ/ of the control than to its BP counterpart. L2 /u/ appears to show a progression towards the TL, as it is more centralized in the vowel space than its BP counterpart. With regards to L2 /o/, while it is phonetically similar to BP /o/, both mean productions are more fronted than in the intermediate group and therefore closer to TL /o/. In other words, the similar vowels /i, e, ɛ, u, o/ appear to show a progression towards the TL vowels.

The remaining vowels–that is, the new vowels /ɪ, æ, ʌ, ʊ, ɑ/–are produced with mixed results. In Figure 14, it can be seen that while the advanced participants' have succeeded in contrasting /i/ and /ɪ/, the mean production of /ɪ/ now appears to have assimilated to /e/. However, as will be illustrated in Section 4.5.2.2, this simply due to the mean production of these vowels failing to show the complete picture. There also appears to

be no clear phonetic category established for /æ/, which is assimilated to L2 /ɛ/ (or the two of them have combined to form a new phonetic category entirely). L2 /ʌ/ appears to be more open (and therefore more nativelike) than the mean production of the intermediate group, as it occurs approximately 75 Hz from the TL /ʌ/ rather than approximately 175 Hz, as is the case with the intermediate group (cf. Figure 12, Section 4.5.1). The mean L2 production of /ʊ/ displays a similarly modest progression towards the TL /ʊ/, but is still produced relatively close to L2 /u/. Finally, /ɑ/ appears to be produced *relatively* closely to the control group, but–like the intermediate group's mean production–could be viewed as an intermediary between the CE /ɑ/ and BP /ɔ/.

However, as was the case with the intermediate group, the mean formant values of the advanced group's productions do not provide an adequate picture of their vowel space and the data need to be treated with more depth in order to answer the present study's research questions and confirm of reject its hypotheses.

4.4.2.1 Hypothesis A. Hypothesis A, as it pertains to the advanced group, predicts that the L2 vowels that are similar to preexisting BP vowels (i.e., /i, e, ɛ, u, o/) will be an intermediary between the BP and CE L1 vowels. In addition to a visual comparison of the mean productions of the L2, BP, and TL vowels, the normalized formant values of the productions were compared to one another to assess whether the L2 vowels resembled their BP counterparts, the TL vowels, or an intermediary form (see Table 23).

Table 23. Mean F1 and F2 Values in Hertz of the Similar BP, L2, and TL Vowels

Vowel	BP		L2		TL	
	F1	F2	F1	F2	F1	F2
/i/	328	2013	318	2060	302	2032
/e/	395	1851	402	1924	397	1933
/ɛ/	523	1763	588	1663	563	1618
/u/	360	1152	354	1431	337	1596
/o/	435	1176	441	1203	454	1267

As was the case with the intermediate group, establishing whether some of the L2 vowels are being produced closer to the BP or TL counterpart is difficult due to the phonetic similarity of the phones. The vowels /i/, /e/, and /o/ in particular appear to differ little between BP, the interlanguage of the advanced group, and the CE productions of the control group with the F1 and F2 of each L2 vowel showing a similarity to both its BP and TL counterparts of over 95%. According to Figure 14 and Table 23, the mean L2 production of /i/ is slightly more fronted than either the BP or TL production and occurs somewhere between the two in terms of height. Meanwhile, L2 /e/ is more open than the BP or TL and occurs between the two in terms of frontness. Finally, L2 /o/ occurs between BP and TL in terms of height and frontness. However, while the L2 vowels /i/, /e/, /o/ may display intermediary F1 and/or F2 levels, the differences between the L2, BP, and TL mean productions are too slight to state definitely whether the participants are producing an intermediary form.

The L2 vowel /u/ is perhaps the only vowel that shows clear evidence confirming the hypothesis. This is, of course, due to the fact that BP /u/ and CE /u/ are drastically different in terms of their frontness. In Figure 14, the mean TL /u/ occurs in the middle of the vowel space with a mean F2 of 1,596 Hz, while BP /u/ is further back with a mean F2

of 2,013 Hz. With regards to F2, L2 /u/ is clearly occurring between the two with a mean F2 of 1,431 Hz.

Finally, the L2 /ɛ/ occured more back in the vowel space than its BP counterpart and had an F2 with a 97.2% similarity to the F2 of the control (as opposed to a 94.3% similarity with the BP /ɛ/). Meanwhile, it is more open than either the BP or TL counterpart and occurs close to L2 /æ/, indicating that the advanced group has established a single phonetic category for /ɛ/ and /æ/ after having failed to contrast the pair.

4.4.2.2 Hypotheses B and C. The second hypothesis related to production predicts that the L2 (CE) vowels that are *new* (i.e., those that do not occur in the BP inventory; /ɪ, æ, ʊ, ʌ, ɑ/) will be produced with formant values similar to native English speaker formant values in the advanced proficiency group. The third hypothesis pertaining to production predicts that vowels too similar to an existing phonetic category will remain persistently difficult to acquire across the proficiency groups, with the new L2 sound and the closest preexisting L1 sound merging into an intermediary form.

As in the intermediate proficiency group, this acquisition is viewed in terms of the of the participants' ability to not only produce vowels that are phonetically similar to their TL counterparts, but also to display a contrast between various vowel pairs. With this in mind, statistical tests were carried out the advanced group and the control group's productions of 10 CE vowel pairs (/i/-/ɪ/, /ɪ/-/e/, /e/-/ɛ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/o/, /o/-/ɑ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, and /ʌ/-/æ/) in order to see whether the EDs differed significantly between the two groups. Levene's test for equality of variance yielded a nonsignificant p-value in a comparison of the advanced and control groups ($F = 3.4$, $p = .0676$), so two-sample *t*-tests were used. The mean EDs of the vowel pairs for the control group and the advanced group, the similarity

between the two groups, and the results of the *t*-test comparing the two groups are displayed in Table 24.

Table 24. Mean Values of the Euclidean Distances Between the CE Vowels Pairs for the Control and Advanced Participants, Percentage of L1 vs. L2 Similarity, and *t*-tests.

Vowel Pair	Control (Hz)	L2 (Hz)	L1 vs. L2 Similarity	*t*-test
/i/-/ɪ/	307	185	60.2%	$t(10) = -2.71, p = .022$
/ɪ/-/e/	175	118	67.4%	$t(10) = -1.43, p = .18$
/e/-/ɛ/	372	349	93.8%	$t(10) = -.406, p = .693$
/ɛ/-/æ/	109	45	41.3%	$t(10) = -3.72, p = .004$
/u/-/ʊ/	242	120	49.6%	$t(10) = -2.49, p = 0.032$
/ʊ/-/o/	142	210	67.6%	$t(10) = 1.07, p = .309$
/o/-/ɑ/	179	178	99.4%	$t(10) = -.08. p = .938$
/ʊ/-/ʌ/	139	242	57.4%	$t(10) = 1.91, p = .085$
/ʌ/-/ɑ/	225	305	73.7%	$t(10) = 2.57, p = .0277$
/ʌ/-/æ/	163	193	85%	$t(10) = .89, p = .394$

The results of the *t*-tests indicate that 4 of the vowel pairs showed a significant difference between the advanced L2 group and the control: /i/-/ɪ/ ($t(10) = -2.71, p = .022$), /u/-/ʊ/ ($t(10) = -2.49, p = .032$), /ɛ/-/æ/ ($t(10) = -3.72, p = .004$), and /ʌ/-/ɑ/ ($t(10) = 2.57, p = .0277$).

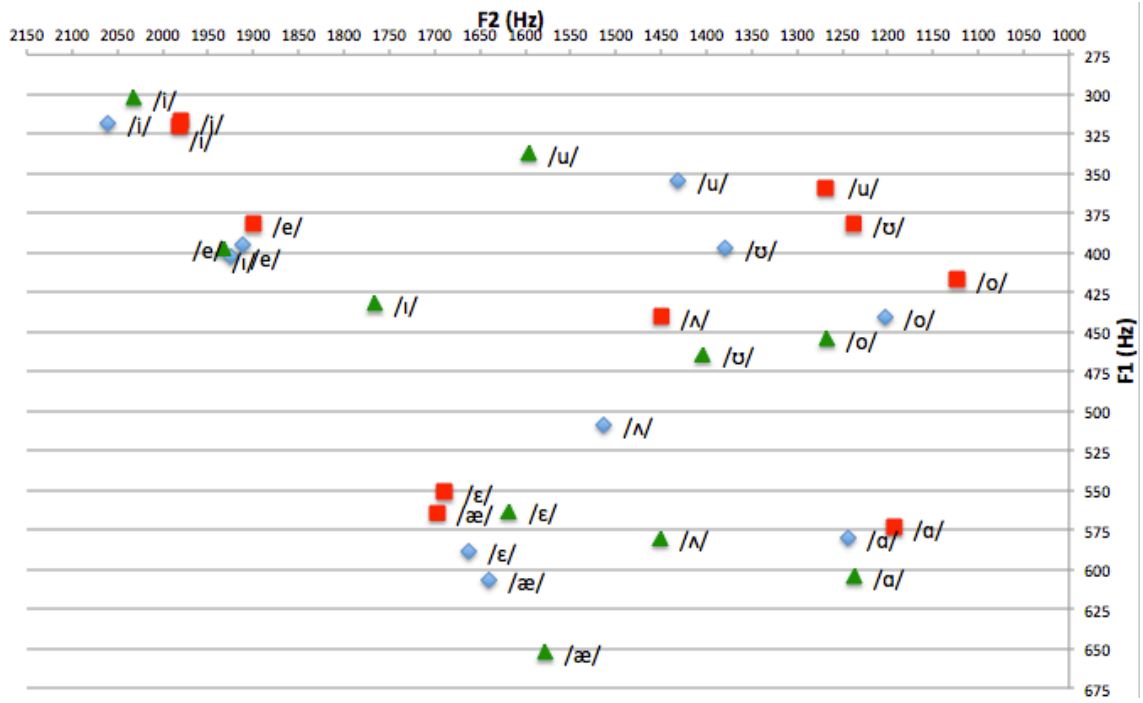

Figure 15. Scatter plot displaying the mean formant values of the advanced proficiency group's L2 vowels (blue diamonds), the intermediate proficiency group's L2 vowels (red squares), and the control group's L1 vowels (green triangles).

The advanced group's production of /ɪ/ shows clear improvement over the intermediate group. While the advanced speaker's mean ED for the /i/-/ɪ/ is still significantly different than the control, its similarity to the control is drastically higher than the intermediate group (60.2%, as opposed to 9.7%)(see Figure 15 for a visualization comparing the intermediate and advanced groups). The data indicates that while the ED of the advanced may not be nativelike, a contrast has certainly been established between the tense-lax /i/-/ɪ/ pair. In Figure 14, the vowels /ɪ/ and /e/ appear to be phonetically similar, however, the *t*-tests show that the advance group's productions of the /ɪ/-/e/ vowel pair does not differ significantly from the control group ($t(10) = -1.43$, $p = .18$). Figure 16 shows that the majority of the advanced group's productions of /ɪ/ were more open than /e/, but some more closed productions of the vowel (possibly due to

participants failing to produce the /i/-/ɪ/ contrast) skewed the mean. While the results of the *t*-tests do not confirm Hypothesis B with regards to /ɪ/, they appear to indicate that the L2 learners are progressing towards more nativelike productions of the vowel.

L2 /æ/ appears to have not been acquired by the advanced speakers, with the ED of the /ɛ/-/æ/ pair being significantly smaller ($t(10) = -3.72$, $p = .004$) than that of the control group. Furthermore, Figure 16 shows no clear separate phonetic categories for /ɛ/ and /æ/. As previously stated, the data indicate that the advanced speakers appear to have established a single phonetic category for both /ɛ/ and /æ/.

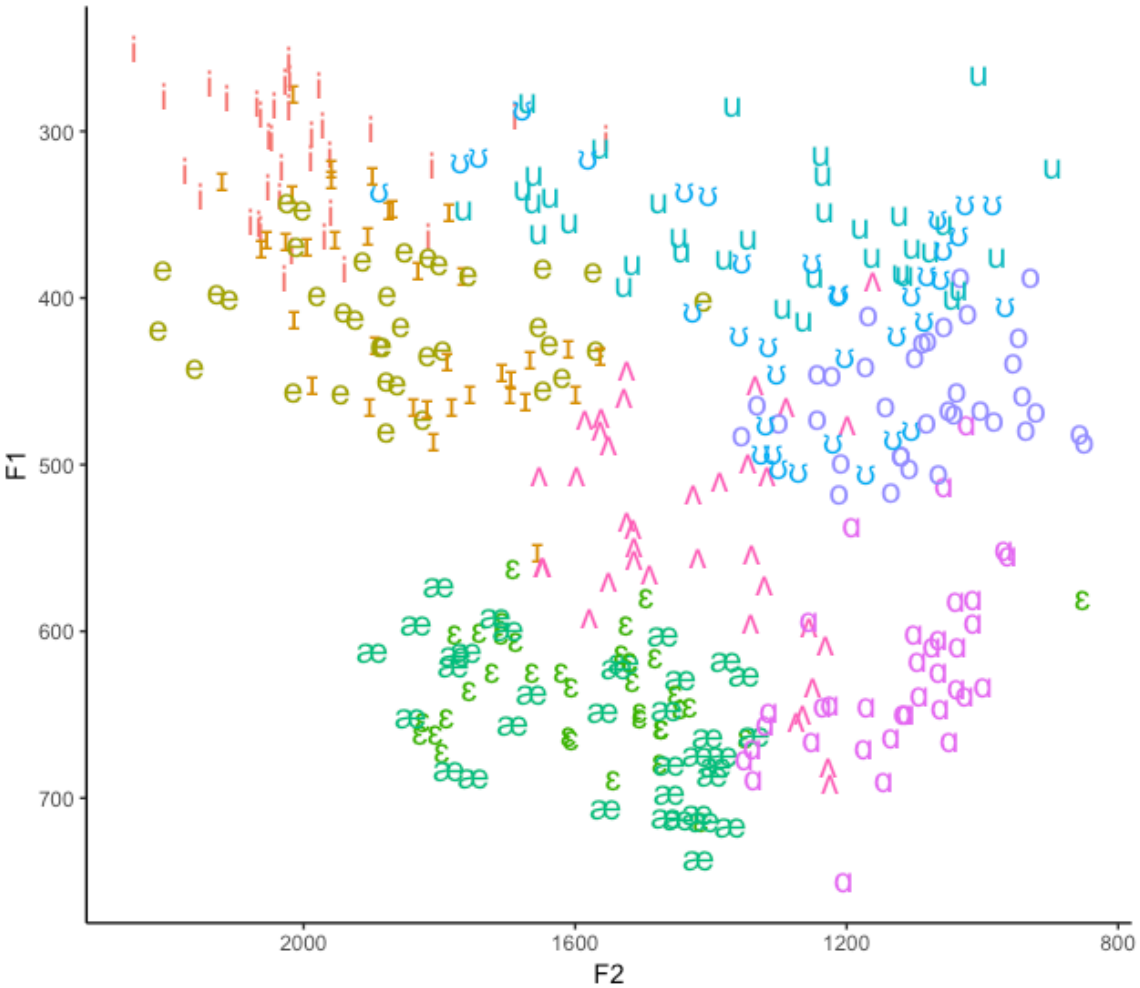

Figure 16. Scatter plot of all L2 vowel tokens produced by the advanced proficiency group.

/ɑ/ is produced more open than in the intermediate group, and therefore more similar to the control group. A comparison of the /o/-/ɑ/ pair between the advanced and control group indicates a similarity of 99.4%, which appears to confirm the hypothesis. While there was a significant difference in the EDs of the /ʌ/-/ɑ/, this appears to be due to /ʌ/ being produced with a high degree of variability, but on average more closed than in the control group.

Finally, the vowel /ʊ/ appears to have not been acquired in the advanced group. Not only is the ED of the /u/-/ʊ/ significantly smaller ($t(10) = -2.49$, $p = 0.032$) than the in the control, but it is smaller than the intermediate group. However, Figure 15 indicates that a number of /ʊ/ were produced extremely centralized in the vowel space and resembled /i/ phonetically, thereby skewing the results. However, there can be no doubt that the vowel is not produced with values similar to the control group.

4.5 Conclusion

In this chapter the results of the production tasks were presented, along with an analysis and discussion of the data generated from the tasks. These analyses sought to either confirm or reject the present study's hypotheses that pertained to the production of the CE vowels by native speakers of BP.

In the case of the intermediate group, the analysis appears to have confirmed Hypothesis A for the most part. The L2 vowels /u, o, ɛ/ are phonetically more similar to their BP counterparts than the TL tokens, while /i, e/ appear to be produced similarly across languages, making it difficult to confirm or reject the hypothesis. Hypothesis B is confirmed for the vowels /ɪ, æ, ʊ/, which the intermediate speakers are unable to distinguish from /i, ɛ, u/. Meanwhile, /ʌ/ and /ɑ/, while not being assimilated to a

preexisting category, are not shown to have been definitely acquired by the participants, thereby confirming Hypotheses B and C.

Hypothesis A was partially confirmed in the case of the advanced group. L2 /u/ was shown to be produced at an intermediary point phonetically between TL /u/ and BP /u/. However, as was the case with the intermediate group, /i, e, o/ were shown to be phonetically similar across languages, making confirmation or rejection of the hypothesis difficult. Hypothesis B was mainly rejected; while the advanced group showed definite progress over the intermediate group in terms of acquiring the new vowels and producing various contrasts, they were often phonetically dissimilar from the control group. Finally, Hypothesis C was confirmed in the case of the vowel /æ/, which the advanced participants merged with /ɛ/ into an intermediary form.

In the following chapter, these production data are drawn upon again in order to answer this study's questions regarding the connection between production and perception of the CE vowels by native speakers of BP.

5. Perception Results & Analysis

In this chapter, the results of the perception tests carried out in this study are reported, along with an analysis of these results. Both an identification task (see Appendix F) and a discrimination task (see Appendix G) were completed by all three groups (i.e., the intermediate and advanced proficiency L2 experimental groups and the native speaker control group).

The present chapter begins with a review of this study's guiding questions related to perception of the CE vowel sounds by Brazilian ESL speakers, as well as the hypotheses that were generated from these questions. Next, the results of the identification task and the discrimination task are reported, organized by group. Finally, an analysis of the data generated from these tasks–also organized by group– is provided in order to confirm or reject the study's hypotheses.

5.1 Perception Research Questions and Hypotheses

This study attempts to investigate the acquisition of the CE vowels by native speakers of BP. In order to fully investigate this acquisition, the perception of these L2 vowel sounds must be examined in addition to the production in order to provide a fuller account of the participants' acquisition of these sounds. In order to guide this investigation, the following research questions related to perception were posed:

2. Concerning CE vowel perception, how accurately will the participants be able to identify the CE vowels in the identification task? How accurately will all participants discriminate the English vowel pairs during the discrimination task? How will the rates of

accurate discrimination differ between the two experimental groups and the control group?

Additionally, the following questions were developed in order to investigate the link between production and perception of the CE vowels:

3. What is the relationship between the production and perception of English vowels by native BP speakers and how does this relationship between production and perception differ between the intermediate learner and advanced learner groups?

From these research questions, the theoretical framework of the SLM (Flege, 1995; Flege, 2005), and the findings of previous studies, the following hypotheses pertaining to perception were developed:

D. CE vowels that are similar to L1 (BP) vowels (/i, e, ɛ, u, o/) will be perceived accurately by both the intermediate and advanced groups, but new vowels (/ɪ, æ, ʊ, ʌ, ɑ/) will not be perceived well by the intermediate group.

E. Participants' perception will outperform their production, with participants being able to discriminate and identify some vowel contrasts that they are not able to produce reliably.

F. Perception and production will be linked, with vowel contrasts that are poorly perceived on the discrimination task being poorly produced in the production task. Similarly, vowels that show lower rates of identification on the identification task will be poorly produced.

To test these hypotheses, two perception tasks were designed and administered: an identification task and a discrimination task. The tasks were completed by both the control group–in order to provide a baseline for comparison–and the two experimental groups.

The identification consisted of a forced choice identification test with a closed data set containing each of the ten CE vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/) as possible responses (see Table 12, Section 3.4.3). The stimuli consisted of 30 trials (three tokens for each of the ten CE vowels, see Appendix F for a list of all 30 words). During the task participants listened to the tokens and were asked to choose the response option that contained the same vowel sound as what they heard (e.g., participants would hear the stimuli "pet" and be tasked with selecting which of ten answer choices contained the vowel they heard, which in this case would be "bet", § Appendix F).

The oddity discrimination task was designed to test the participants' discrimination rate of ten English vowel pairs: /i/-/ɪ/, /ɪ/-/e/, /e/-/ɛ/, /ɛ/-/æ/, /u/-/ʊ/, /ʊ/-/o/, /o/-/ɑ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, and /ʌ/-/æ/. Following the design of Rauber et al. (2005), the stimuli consisted of 120 trials of three items (eight trials for each of the 10 vowel contrasts, plus four trials of 10 non-contrasted vowels; see Appendix G for a list of all 120 trials). Each trial contained either the same target vowel in each sentence or one odd

item (i.e., a word containing a different vowel than the other two). Participants were then asked to indicate which of the three sentences contained the odd vowel, or whether all sentences contained the same vowel. For example, participants would hear the stimuli "Now I say *kit.* Now I say *pit*. Now I say *Kate*" and would need to select whether the first, second, or third phrase contained an odd vowel, or whether none did (in this case the correct response would be Word C).

The data collected from the identification and discrimination tests were quantified and organized to show the identification rates for identification of the CE vowels and the rates of accurate discrimination between the vowel contrasts for each of the participants. The identification and discrimination rates of the experimental participants were compared between the intermediate and advanced proficiency groups and the control group. The results of the perception test were also compared to the data gathered from the production test in order to investigate the relationship between production and perception.

5.2 Perception Results

5.2.1 Control participants. The native CE speaking control participants ($N = 6$) completed both perception tasks for this study, with a mean performance of 98% ($SD = 2.7$) across the two perception tasks. While the control participants–unsurprisingly–made very few errors on either the identification or discrimination task, their results are nevertheless included to provide baseline data for comparison and to demonstrate the validity of the tasks.

5.2.1.1 Identification task results. The control group as a whole correctly identified 98.9% ($SD = 2.7$) of the vowel tokens in the identification task. The average

time to complete the task was 3.22 minutes (*SD* = 0.8). Table 25 displays the identification rate and average response time, grouped by vowel, for the control group.

Table 25. Control Group's Mean and Median Identification Rates (IR), Standard Deviation, and Response Times (in seconds) for the Identification Task, Grouped by Vowel

	/i/	/ɪ/	/e/	/ɛ/	/æ/
	N = 18	*N* = 18	*N* = 18	*N* = 18	*N* = 18
Mean IR (%)	100	100	94.4	94.4	100
Median IR (%)	100	100	100	100	100
Standard Deviation (%)	0	0	13.6	13.6	0
Response Time	4.33	8.46	4.38	3.67	3.9
	/ʌ/	**/ɑ/**	**/o/**	**/ʊ/**	**/u/**
	N = 18	*N*= 18	*N* = 18	*N* = 18	*N* = 18
Mean IR (%)	100	100	100	100	100
Median IR (%)	100	100	100	100	100
Standard Deviation (%)	0	0	0	0	0
Response Time	8.25	7.11	4.66	12.89	6.67

5.2.1.2 Discrimination task results. The control group had an average overall discrimination rate of 97.1% (*SD* = 3) in the discrimination task. The average time to complete the task was 32.8 minutes (*SD* = 3.9). Table 26 displays the average discrimination rates for the odd vowel pairs (i.e., the triads in which one of the three sentences contained an odd vowel), while Table 27 displays the average discrimination rates in the triads in which all vowels were the same.[10]

[10] The odd vowel triads and the "all the same" triads are presented separately as most vowels occur in multiple vowel pairs, making it impossible to combine them without discussing them in terms of individual vowels rather than vowel pairs, as is done in the analysis section.

Table 26. Control Group's Mean and Median Discrimination Rates (DR), Standard Deviation, and Response Times (in seconds) for the Odd Vowel pairs in the Discrimination Task, Grouped by Vowel Pair

	/i/-/ɪ/	/ɪ/-/e/	/e/-/ɛ/	/ɛ/-/æ/	/u/-/ʊ/
	N = 48	*N* = 48	*N* = 48	*N* = 48	*N* = 48
Mean DR (%)	97.9	97.9	97.9	93.8	97.9
Median DR (%)	100	100	100	93.8	100
Standard Deviation (%)	5.1	5.1	5.1	6.8	5.1
Response Time	20	15	21.4	21	18.7
	/ʊ/-/o/	**/o/-/ɑ/**	**/ʊ/-/ʌ/**	**/ʌ/-/ɑ/**	**/ʌ/-/æ/**
	N = 48	*N* = 48	*N* = 48	*N* = 48	*N* = 48
Mean DR (%)	97.9	97.9	91.7	97.9	100
Median DR (%)	100	100	93.8	100	100
Standard Deviation (%)	5.1	5.1	10.2	5.1	0
Response Time	15.6	16.8	16.8	15.2	10.9

Table 27. Control Group's Mean and Median Discrimination Rates (DR), Standard Deviation, and Response Times (in seconds) for the Identical Vowels in the Discrimination Task, Grouped by Vowel

	/i/	/ɪ/	/e/	/ɛ/	/æ/
	N = 24	*N* = 24	*N* = 24	*N* = 24	*N* = 24
Mean DR (%)	100	100	100	91.7	95.8
Median DR (%)	100	100	100	100	100
Standard Deviation (%)	0	0	0	20.4	10.2
Response Time	15.2	13.9	13.8	15.9	12.7
	/u/	**/ʊ/**	**/o/**	**/ɑ/**	**/ʌ/**
	N = 24	*N* = 24	*N* = 24	*N* = 24	*N* = 24
Mean DR (%)	100	91.7	95.8	100	95.8
Median DR (%)	100	100	100	100	100
Standard Deviation (%)	0	12.9	10.2	0	10.2
Response Time	21.7	15.3	17.6	8.9	12.8

5.2.2 Intermediate English proficiency participants. The intermediate English proficiency group (*N* = 8) had a mean accuracy rate of 59.17% (*SD* = 18.5) across both perception tasks and the sections below examines each task individually. The intermediate group displayed a higher variation in rates of identification and

discrimination than either the advanced group or the control group, especially in the identification task, as will be shown below.

5.2.2.1 Identification task results. The average overall rate of identification for the intermediate proficiency group was 55.8% (*SD* = 22.8). However, as evinced by the high standard deviation, there was a considerable amount of variation among the participants, with overall rates of identification ranging from 13.3% (IF1) to 76.7% (IF4). The average time to complete the task for the intermediate group was 4.74 minutes (*SD* = 0.8), while the average time to complete the task for the control group was 3.18 minutes (*SD* = 0.8). Table 28 displays the identification rate and average response time, grouped by vowel, for the intermediate group

Table 28. Intermediate Group's Mean and Median Identification Rates (IR), Standard Deviations, and Response Times (in seconds) for the Identification Task, Grouped by Vowel

	/i/	**/ɪ/**	**/e/**	**/ɛ/**	**/æ/**
	N = 24	*N* = 24	*N* = 24	*N* = 24	*N* = 24
Mean IR (%)	58.3	58.3	75	54.2	66.7
Median IR (%)	66.7	66.7	83.3	50	66.7
Standard Deviation (%)	29.5	29.5	34.5	35.3	25.2
Response Time	9.91	13.07	19.53	3.32	13.68
	/ʌ/	**/ɑ/**	**/o/**	**/ʊ/**	**/u/**
	N = 24	*N* = 24	*N* = 24	*N* = 24	*N* = 24
Mean IR (%)	29.2	66.7	62.5	54.2	33.3
Median IR (%)	16.7	83.3	66.7	50	16.7
Standard Deviation (%)	37.5	43.6	33	24.8	33
Response Time	7	7.43	8.12	6.34	6.44

5.2.2.2 Discrimination task results. The intermediate group had an average overall discrimination rate of 62.9% (*SD* = 14.1) in the discrimination task. The average time to complete the task was 33 minutes (*SD* = 3.3). The variation was much lower in

the discrimination task, as is shown in tables 29 and 30. Table 29 reports the average discrimination rates for the odd vowel pairs, while Table 30 reports the average discrimination rates in the triads in which all vowels were the same.

Table 29. Intermediate Group's Mean and Median Discrimination Rates (DR), Standard Deviation, and Response Times (in seconds) for the Odd Vowel Pairs in the Discrimination Task, Grouped by Vowel Pair

	/i/-/ɪ/	/ɪ/-/e/	/e/-/ɛ/	/ɛ/-/æ/	/u/-/ʊ/
	N = 64	*N* = 64	*N* = 64	*N* = 64	*N* = 64
Mean DR (%)	56.3	78.1	82.8	34.4	56.3
Median DR (%)	50	81.3	87.5	31.3	56.3
Standard Deviation (%)	29.1	21.9	19.9	18.6	27.5
Response Time	16.7	14.8	18	14.2	17.7
	/ʊ/-/o/	**/o/-/ɑ/**	**/ʊ/-/ʌ/**	**/ʌ/-/ɑ/**	**/ʌ/-/æ/**
	N = 64	*N* = 64	*N* = 64	*N* = 64	*N* = 64
Mean DR (%)	68.8	84.4	67.2	57.8	45.3
Median DR (%)	68.8	87.5	62.5	56.3	56.3
Standard Deviation (%)	26.7	17.3	22	24	24.9
Response Time	14.8	16.2	15.9	17.4	15.8

Table 30. Intermediate Group's Mean and Median Discrimination Rates (DR), Standard Deviations, and Response Times (in seconds) for the Identical Vowels in the Discrimination Task, Grouped by Vowel

	/i/	/ɪ/	/e/	/ɛ/	/æ/
	N = 32	*N* = 32	*N* = 32	*N* = 32	*N* =32
Mean DR (%)	71.9	53.1	62.5	53.1	75
Median DR (%)	75	50	75	50	75
Standard Deviation (%)	50	36.4	26.7	36.4	26.7
Response Time	15.4	17.1	22.6	14.8	19.9
	/u/	**/ʊ/**	**/o/**	**/ɑ/**	**/ʌ/**
	N = 32	*N* = 32	*N* = 32	*N* = 32	*N* = 32
Mean DR (%)	56.3	46.9	62.5	87.5	56.3
Median DR (%)	75	37.5	75	100	62.5
Standard Deviation (%)	34.7	33.9	26.7	18.9	32
Response Time	14.5	15.5	18.5	17.6	15.4

5.2.3 Advanced English proficiency participants. The advanced English proficiency group (*N* = 6) had a mean performance of 80.7% (*SD* = 7.4) across both

perception task (as before, the performance on each task is discussed individually). The advanced participants showed much less variation in their performance on the tasks than the intermediate group. However, there was still more variation than in the control group, as is shown in the tables 31 and 32.

5.2.3.1 Identification task results. The average overall rate of identification for the advanced proficiency group was 80.5% (*SD* = 9.5). The average time to complete the task was 4.14 minutes (*SD* = 1.4). Table 31 displays the identification rate and average response time, grouped by vowel, for the advanced group.

Table 31. Advanced Group's Mean and Median Identification Rates (IR), Standard Deviation, and Response Times (in seconds) for the Identification Task, Grouped by Vowel

	/i/	/ɪ/	/e/	/ɛ/	/æ/
	N = 18	*N* = 18	*N* = 18	*N* = 18	*N* = 18
Mean IR (%)	88.9	83.3	100	61.1	72.2
Median IR (%)	100	83.3	100	66.7	83.3
Standard Deviation (%)	17.2	18.3	0	25.1	38.9
Response Time	16.67	16.49	3.84	12.8	4.51
	/ʌ/	**/ɑ/**	**/o/**	**/ʊ/**	**/u/**
	N = 18	*N* = 18	*N* = 18	*N* = 18	*N* = 18
Mean IR (%)	77.8	94.4	100	61.1	66.7
Median IR (%)	83.3	100	100	66.7	66.7
Standard Deviation (%)	27.2	13.6	0	13.6	29.8
Response Time	5.31	7.51	4.01	4.97	6.74

5.2.3.2 Discrimination task results. . The advanced group had an average overall discrimination rate of 80.8% (*SD* = 5.4) in the discrimination task. The average time to complete the task was 31.9 minutes (*SD* = 3.2). Table 32 below displays the average discrimination rates for the odd vowel pairs, while Table 33 displays the average discrimination rates in the triads in which all vowels were the same.

Table 32. Advanced Group's Mean and Median Discrimination Rates (DR), Standard Deviations, and Response Times (in seconds) for the Odd Vowel Pairs in the Discrimination Task, Grouped by Vowel Pair

	/i/-/ɪ/	/ɪ/-/e/	/e/-/ɛ/	/ɛ/-/æ/	/u/-/ʊ/
	N = 48	*N* = 48	*N* = 48	*N* = 48	*N* = 48
Mean DR (%)	87.5	100	97.9	56.3	83.3
Median DR (%)	93.8	100	100	62.5	81.3
Standard Deviation (%)	15.8	0	5.1	10.5	15.1
Response Time	14.7	16.2	15.4	14.9	17.7
	/ʊ/-/o/	**/o/-/ɑ/**	**/ʊ/-/ʌ/**	**/ʌ/-/ɑ/**	**/ʌ/-/æ/**
	N = 48	*N* = 48	*N* = 48	*N* = 48	*N* = 48
Mean DR (%)	93.8	91.7	85.4	77.1	75
Median DR (%)	100	93.8	87.5	87.5	75
Standard Deviation (%)	10.5	10.2	18.4	25.5	17.7
Response Time	15.3	15.1	17	14.7	13.4

Table 33. Advanced Group's Mean and Median Discrimination Rates (DR), Standard Deviation, and Response Times (in seconds) for the Identical Vowels in the Discrimination Task, Grouped by Vowel

	/i/	/ɪ/	/e/	/ɛ/	/æ/
	N = 24	*N* = 24	*N* = 24	*N* = 24	*N* = 24
Mean DR (%)	62.5	58.3	91.7	58.3	83.3
Median DR (%)	50	62.5	100	62.5	75
Standard Deviation (%)	30.6	30.3	12.9	46.5	12.9
Response Time	15.5	18.4	13.5	15.7	14.9
	/u/	**/ʊ/**	**/o/**	**/ɑ/**	**/ʌ/**
	N = 24	*N* = 24	*N* = 24	*N* = 24	*N* = 24
Mean DR (%)	66.7	45.8	83.3	87.5	91.7
Median DR (%)	62.5	50	100	100	100
Standard Deviation (%)	30.3	43.1	30.2	30.6	20.4
Response Time	19.6	13.9	17.2	15	26.4

5.3 Perception Analysis

In the following section, an analysis of the data generated from the perception tasks is presented. As was the case with the analysis of the production tasks, the analysis of the perception tasks is organized into two parts: one section for the intermediate L2 learners and another for the advanced L2 learners. Each of these sections is further

divided by the hypotheses pertaining to perception (i.e., Hypotheses D, E, and F) with the goal of confirming or rejecting them and answering the research questions of this study.

5.3.1 Intermediate English proficiency participants.

5.3.1.1 Hypothesis D. Hypothesis D, as it pertains to the intermediate group, postulates that the similar CE vowels (i.e., those that share an IPA symbol with a vowel in BP; /i, e, ɛ, u, o/) will be perceived accurately, but new vowels (/ɪ, æ, ʊ, ʌ, ɑ/) will not be perceived well.

In terms of the identification task, this hypothesis is partially rejected for the intermediate group, as the mean identification rate for the similar vowels is 56.6% (*SD* = 15.37), while the mean identification rate for the new vowels is only slightly lower at 55% (*SD* = 15.6). This appears to indicate that neither the similar nor the new vowels were identified accurately.

Furthermore, the identification task does not provide adequate evidence to confirm or reject Hypothesis D due to its design. As evidenced in Chapter 4, the intermediate group conflates several CE vowels pairs to varying degrees, namely /i/-/ɪ/, /ɛ/-/æ/, and /u/-/ʊ/. Therefore, it should be expected that the participants have difficulty determining whether a given vowel token, for example “keep”, is /i/ or /ɪ/, regardless of the fact that they possess a phonetic category for /i/. Finally, the identification rate of the similar vowels is skewed by the low identification rate of /u/ (39%), which is phonetically quite different in CE and BP, despite sharing a symbol in the IPA. If the identification task results for /u/ are removed from the data set the average identification rate for the similar vowels raises to 62.5% (*SD* = 33).

The results of the discrimination task also fail to provide satisfactory evidence in support of Hypothesis D. In order to analyze the data in terms of similar and new vowels, the discrimination rates for the odd vowel triads and the "all the same" triads were combined and grouped by vowel. Table 34 below displays the mean and median discrimination rates for the CE vowels, while Figure 17 provides a visualization of the data in the form of a series of box plots.

Table 34. Intermediate Group's Mean and Median Discrimination Rates (DR), Standard Deviation for the Discrimination Task, Grouped by Vowel

Similar L2 Vowels	**/i/**	**/e/**	**/ɛ/**	**/u/**	**/o/**	**Average**
	N =96	*N* = 160	*N* = 160	*N* = 96	*N* = 160	*N* = 672
Mean DR (%)	64	74.5	56.8	56.25	71.9	64.69
Median DR (%)	68.8	75	50	68.75	75	67.51
Standard Deviation (%)	28.8	23.7	32.3	30.3	24.8	27.98
New L2 Vowels	**/ɪ/**	**/æ/**	**/ʊ/**	**/ʌ/**	**/ɑ/**	**Average**
	N = 160	*N* = 160	*N* = 224	*N* = 224	*N* = 160	*N* = 928
Mean DR (%)	62.5	51.6	59.8	56.6	76.6	61.42
Median DR (%)	62.5	50	62.5	62.5	81.3	63.76
Standard Deviation (%)	30.6	28.6	27.9	25.9	23.7	27.34

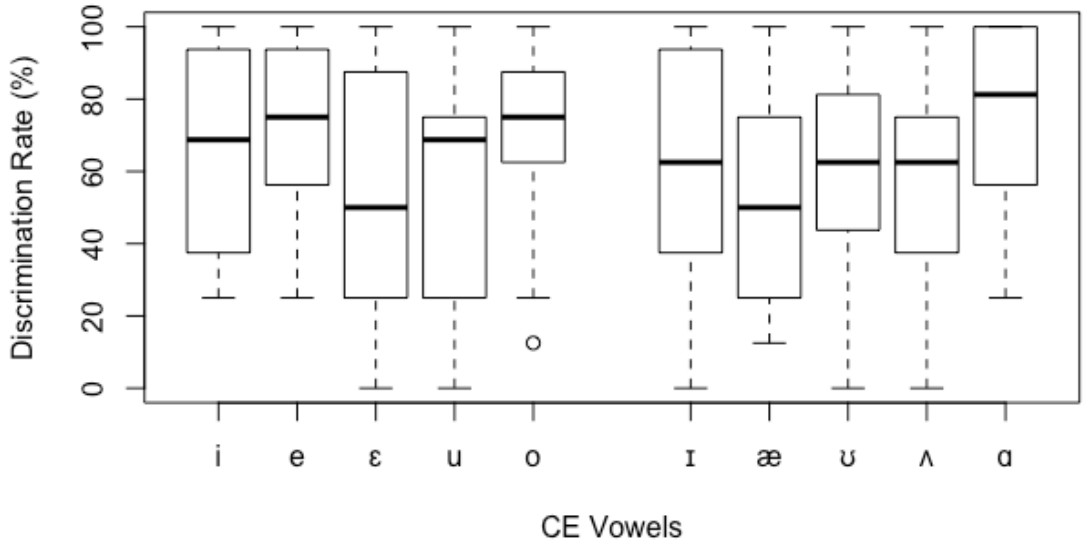

Figure 17. Box plots displaying the mean discrimination rates of the CE vowels by the intermediate proficiency group. Normative bars show the standard deviation from the mean, while dots represent statistical outliers.

As can be observed in Table 34, the overall rate of discrimination for the similar vowels (64.69%) does not differ considerably from the new vowels (61.42%), although the rate of discrimination for the new vowels is lower. An independent sample *t*-test showed no significant difference between the rates of discrimination for the similar and new vowels ($t(220) = 1.18$, $p = .24$). Like the identification task, the issue with the discrimination task could be that because many of the new vowels of CE are conflated with preexisting phonetic categories (e.g., /ɪ/ and /i/, /æ/ and /ɛ/), the rates of discrimination are not easily divided into the categories of "similar" and "new" vowels, as is discussed in Chapter 6.

While the results of the perception tasks do not support the hypothesis that similar vowels will be perceived accurately, the data do provide evidence that the participants have yet to fully establish phonetic categories for many of the new vowels, as evidenced by their low rates of discrimination from the similar vowels (e.g., the odd vowel was only correctly identified in 56.3% of the /i/-/ɪ/ triads, and in 34.4% of the /ɛ/-/æ/ triads).

5.3.1.2 Hypothesis E. This study's second hypothesis related to perception of the CE vowels states that the participants' perception will outperform their production, with the participants being able to discriminate and identify some vowel contrasts that they are not able to produce reliably. With regards to the intermediate group, this hypothesis is confirmed in the data, with the participants showing some ability to accurately perceive vowel contrasts that they were not able to accurately produce.

In Section 4.5.1.2 the ED between various vowel contrasts produced by the intermediate group were compared to those of the control and five were shown to differ significantly based off of the results of independent sample *t*-tests and therefore not acquired by the intermediate participants: /i/-/ɪ/, /ɛ/-/æ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, /ʌ/-/æ/. A sixth contrast, /u/-/ʊ/, was determined to not have been acquired by the intermediate group, despite a *t*-test failing to yield a significant p-value ($t(12) = -1.6$, $p = 0.13$). While it is impossible to directly compare the phonetic measurements taken from the production task to the participants' performance on the perception test, a comparison of the EDs between vowel contrasts and the rate of discrimination for the same contrasts (see Table 35) is illustrative of the participants' perceptual performance.

Table 35. Intermediate Group Mean Values of the Euclidean Distance (ED) Between the CE Vowel Pairs, Similarity to the Control EDs, Mean Discrimination Rates (DR), and Similarity to the Control DRs

Vowel Pair	**/i/-/ɪ/***	**/ɛ/-/æ/***	**/u/-/ʊ/**
L2 ED (Hz)	30	36	161
L1 ED (Hz)	307	109	242
L1 vs. L2 ED similarity	9.7%	33%	66.5%
Mean DR (%)	56.3	34.4	56.3
L1 vs. L2 DR similarity	57.5%	36.7%	57.5%
Vowel Pair	**/ʊ/-/ʌ/***	**/ʌ/-/ɑ/***	**/ʌ/-/æ/***
L2 ED (Hz)	139	321	307
L1 ED (Hz)	139	225	163
L1 vs. L2 ED similarity	57.7%	70%	53%
Mean DR (%)	67.2	57.8	45.3
L1 vs. L2 DR similarity	73.3%	59%	45.3%

*The EDs of these vowel pairs did not differ significantly ($p<.05$) from the control group.

Regarding the /i/-/ɪ/ contrast, the intermediate participants produced a ED of only 30 Hz in the production task, indicating that their productions of the two vowels were nearly identical. However, the participants demonstrated a mean discrimination rate of 56.3%, which is considerably higher than if they had performed at chance (i.e., 25%). Furthermore, the intermediate group's discrimination rate for the /i/-/ɪ/ contrast shared a 57.5% similarity with the discrimination rate of the control group, while the ED produced by the intermediate group only shared a 9.7% similarity with the control group, which appears to indicate that the intermediate group's ability to perceive the contrast outperforms their ability to produce it. This same pattern of the intermediate participants' perceptual abilities outperforming their production may be observed with the remaining vowel contrasts with one exception: the /ɛ/-/æ/ contrast. In the case of this contrast, the intermediate participants only performed slightly higher than chance on the discrimination task (i.e., 34.4%) and do not appear capable of perceiving or producing the contrast.

5.3.1.3 Hypothesis F. This hypothesis is closely linked to Hypothesis E and predicts, essentially, that vowel pairs and vowels that are poorly discriminated and/or poorly identified in the perception tasks will be poorly produced. In other words, perception and production will be linked.

With regards to the vowel pairs, it is possible to confirm this hypothesis without any further analyses than those already provided in the previous sections. A review of Table 29 (see Section 5.2.2.2) shows that the most poorly discriminated vowel pairs were the very same that were demonstrated to have not been acquired in the analysis of the production tasks (cf. Table 22). In other words, the most poorly discriminated vowel pairs were the most poorly produced, thereby confirming the hypothesis.

With regards to the identification test, the process of confirming or rejecting the hypothesis is not so simple. This difficulty of connecting poorly perceived vowels to poorly produced vowels is due to the fact that the intermediate participants' performance is tied to the conflation of vowel contrasts, rather than the misidentification of individual vowels. While an analysis of the identification test results (see Table 28, Section 5.3.2.1) shows that the vowel /ʌ/ had the lowest identification rate while also being poorly discriminated and produced, it is difficult to draw many conclusions regarding the remaining vowels. The relative similarity between the identification rates of /i/ and /ɪ/ or /ɛ/ and /æ/ could be demonstrative of the aforementioned conflation of these pairs.

5.3.2 Advanced English proficiency participants.

5.3.2.1 Hypothesis D. While Hypothesis D pertains more specifically to the intermediate group, it predicts that the advanced group will accurately perceive the similar vowels (i.e., /i, e, ɛ, u, o/). While no specific predictions were made regarding the

new vowels (i.e., /ɪ, æ, ʊ, ʌ, ɑ/), it can be assumed that the advanced speakers are expected to display both higher discrimination and identification rates than the intermediate group.

In the identification task, the advanced group displayed a mean identification rate of 83.3% (*SD* = 16.5) for the similar vowels and a mean identification rate of 77.8% (*SD* = 11.1) for the new vowels. Like the intermediate group, the advanced proficiency participants performed better at identifying the similar vowels, but the difference was small.

This trend of similar perceptual abilities for both the similar and new vowels is displayed in the results of the discrimination test as well. As was the case with the intermediate group, the discrimination rates for the odd vowel triads and the "all the same" triads were combined and grouped by vowel in order to provide a more direct means of comparison between similar and new vowels. Table 36 displays the mean and median discrimination rates for the CE vowels, while Figure 18 provides a visualization of the data in the form of a series of box plots. In the case of the discrimination task, there was an average discrimination rate of 81.4% (*SD* = 22.3) for the similar vowels, and of 79.6% (*SD* = 23.5) for the new vowels. An independent sample *t*-test showed no significant difference between the discrimination rates for the similar and new vowels (*t*(.73) = 163, t = .46).

Table 36. Advanced Group's Mean and Median Discrimination Rates (DR), Standard Deviation for the Discrimination Task, Grouped by Vowel

Similar L2 Vowels	**/i/**	**/e/**	**/ɛ/**	**/u/**	**/o/**	**Average**
	N = 72	*N* = 120	*N* = 120	*N* = 72	*N* = 120	*N* = 504
Mean DR (%)	75	96.5	70.8	75	89.6	81.4
Median DR (%)	81.3	100	75	75	100	86.3
Standard Deviation (%)	26.7	8.7	32.7	24.4	18.8	22.3
New L2 Vowels	**/ɪ/**	**/æ/**	**/ʊ/**	**/ʌ/**	**/ɑ/**	**Average**
	N = 120	*N* = 120	*N* = 168	*N* = 168	*N* = 120	*N* = 696
Mean DR (%)	81.9	71.5	77.1	82.3	85.4	79.6
Median DR (%)	100	75	87.5	87.5	87.5	87.5
Standard Deviation (%)	26	17.6	30.1	20.5	23.2	23.5

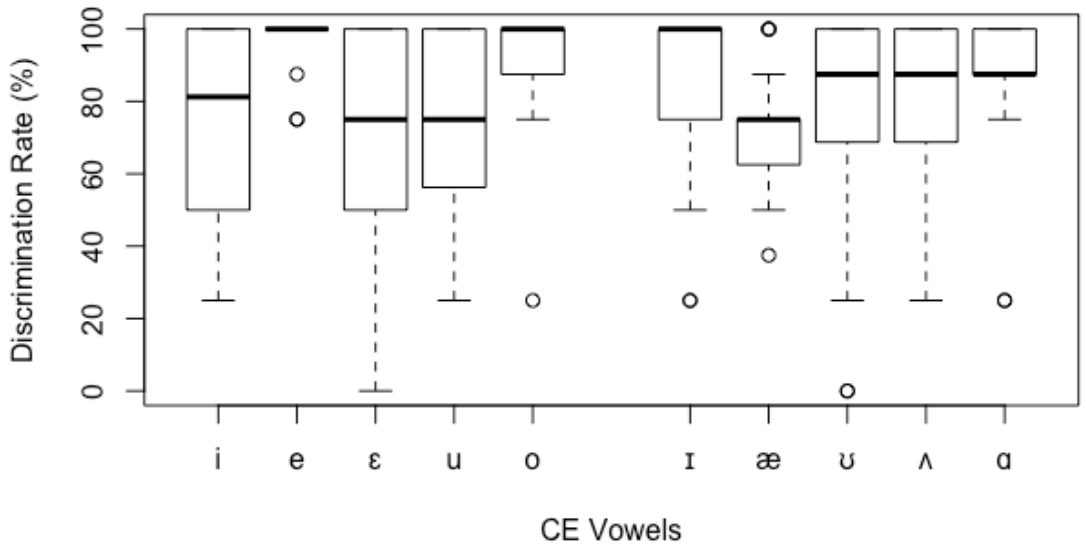

Figure 18. Box plots displaying the mean discrimination rates of the CE vowels by the advanced proficiency group. Normative bars show the standard deviation from the mean, while dots represent statistical outliers.

The results of the perception tests appear to confirm Hypothesis D as it pertains to the advanced group in that the advanced speakers display high rates of identification and

discrimination for both the similar and new vowels, although their performance is still lower than the control. However, while the advanced participants appear to have made considerable progress towards establishing phonetic categories for the new CE vowels, it should be noted that the similarity in identification and discrimination rates for the similar and new vowels indicate some of the same conflation of vowel pairs observed in the intermediate group.

5.3.2.2 Hypothesis E. As was the case with the intermediate group, the data confirm Hypothesis E pertaining to perception, as the advanced proficiency participants show an ability to perceive vowel contrasts that they are not able to produce reliably.

In order to analyze the data with regards to Hypothesis E, the same method was used as with the intermediate group. That is, the EDs between vowel contrasts from the production task were compared to the rates of discrimination for the same vowel contrasts (see Table 37). It should be noted that while six vowel contrasts were considered to have not been acquired in the intermediate group (i.e., /i/-/ɪ/, /ɛ/-/æ/, /ʊ/-/ʌ/, /ʌ/-/ɑ/, /ʌ/-/æ/, /u/-/ʊ/), only 4 were shown to have EDs that differed significantly (i.e., $p<.05$) from the control group in the advanced group: /i/-/ɪ/, /ɛ/-/æ/, /u/-/ʊ/, and /ʌ/-/ɑ/. However, the two additional vowel contrasts (/ʊ/-/ʌ/, /ʌ/-/æ/) were nevertheless included in order to remain consistent across groups.

Table 37. Advanced Group Mean Values of the Euclidean Distances (ED) Between the CE Vowel Pairs, Similarity to the Control (L1) EDs, Mean Discrimination Rates (DR), and Similarity to the Control (L1) DRs

Vowel Pair	**/i/-/ɪ/***	**/ɛ/-/æ/***	**/u/-/ʊ/***
L2 ED (Hz)	185	45	120
L1 ED (Hz)	307	109	242
L1 vs. L2 ED similarity	60.2%	41.3%	49.6%
Mean DR (%)	87.5	56.3	83.3
L1 vs. L2 DR similarity	89.4%	60%	85.1%
Vowel Pair	**/ʊ/-/ʌ/**	**/ʌ/-/ɑ/***	**/ʌ/-/æ/**
L2 ED (Hz)	242	305	193
L1 ED (Hz)	139	225	163
L1 vs. L2 ED similarity	57.4%	73.7%	85%
Mean DR (%)	85.4	77.1	75
L1 vs. L2 DR similarity	93.1%	78.8%	75%

*The EDs of these vowel pairs did not differ significantly ($p<.05$) from the control group.

As was the case with Hypothesis D, the advanced group's results show a progression towards the formation of phonetic categories for the new vowel contrasts, while still having similarities to the intermediate group. Regarding the /i/-/ɪ/ contrast, the advanced participants produced an average ED of 185 Hz (60.2% similar to the control ED), which indicated that while the two vowels were being produced differently, the participants had yet to achieve a *nativelike* ability to produce the contrast. Meanwhile, the advanced participants showed a mean discrimination rate of 87.5%. Furthermore, the similarity between the discrimination rate of the intermediate group and the control is much higher than similarity between the two groups' EDs (i.e., 89.4% vs. 60.2%). This performance on the discrimination task supports the hypothesis that the L2 learners' perception outperforms their production.

The remaining vowel contrasts shown in Table 37 demonstrate a similar pattern of the advanced participants' perceptual abilities outperforming their production with one exception: The /ʌ/-/æ/ contrast. However, as was discussed in Section 4.5.2.2, the

advanced group produced the vowel /ʌ/ with a high level of variability, which makes it difficult to draw definite conclusions from the production data. Finally, while the advanced group showed a greater ability to perceive the /ɛ/-/æ/ contrast than the intermediate group it is worth noting that the contrast still appears to remain persistently difficult to acquire for the advanced L2 learners, as evidenced by the relatively low discrimination rate (56.3%).

5.3.2.3 Hypothesis F. Again, this hypothesis predicts that poorly discriminated vowel contrasts and poorly identified vowels would be similarly poorly produced, thereby demonstrating a connection between perception and production.

As was the case with the intermediate group, this hypothesis is easily confirmed by reviewing the results of the discrimination task (see Table 32, Section 5.2.3.2). The four vowel contrasts that differed significantly from the control group in the production task (/i/-/ɪ/, /ɛ/-/æ/, /u/-/ʊ/, and /ʌ/-/ɑ/)–thereby indicating that they are the most poorly produced–were shown to have among the lowest rates of discrimination (87.5%, 56.3%, 83.3%, and 77.1%). The one exception to this trend is the vowel contrast /ʌ/-/æ/, which was shown to have the second lowest rate of discrimination among the vowel pairs, despite the mean ED of the pair not being significantly different from the control. However, as was mentioned previously, the high variability of the /ʌ/ productions complicates the interpretation of the data.

With regards to the identification test, the same situation encountered with the intermediate group arised. To wit, it is difficult to connect poorly perceived vowels to poorly produced vowels because the participants' performance on both tasks is tied to their conflation of vowel contrasts, rather than the misidentification of individual vowels.

While the results of the identification test show a relative similarity between the identification rates of /i/ and /ɪ/, /ɛ/ and /æ/, and /u/ and /ʊ/, which could be indicative of this conflation of vowel pairs, it is nevertheless difficult to draw any definite conclusions with regards to Hypothesis F.

5.4 Conclusion

In this chapter, the results of the perception tasks were presented along with an analysis and discussion of these results as they pertained to the hypotheses and research questions of the present study.

With regards to Hypothesis D (i.e., both experimental groups will perceive the similar vowels well, but intermediate group will not perceive new vowels accurately), the analysis was not supportive and, thus, the hypothesis was rejected. In the case of both the intermediate group and the advanced group the difference between the identification and discrimination rates of the similar and new vowels was relatively small, although similar vowels were, on average, perceived more accurately. However, as has been discussed previously in this chapter, the results of the identification and discrimination tasks demonstrated that the participants conflated CE vowel contrasts to varying degrees.

Hypothesis E (i.e., participants' perception will outperform their production of the CE vowels) was confirmed. A comparison of the EDs from the production task with the mean discrimination rates clearly showed that both groups' performances on the discrimination task were more similar to the control group than their performances in the CE production task. This same comparison between the results of the production task and the discrimination task confirmed Hypothesis F (i.e., poorly perceived vowel contrasts and vowels will be similarly poorly produced) with regards to the vowel pairs. However,

Hypothesis F was not confirmed with regards to the identification of individual vowels for the same reasons described above regarding Hypothesis D.

6. Discussion

The present study has sought to investigate how native speakers of Brazilian Portuguese (BP) L2 learners of English of two proficiency levels living in Canada produce and perceive the vowels of Canadian English (CE). While previous research has investigated the production and perception of English vowels by Brazilian L2 learners, it has focused either upon learners who have never lived in an English-speaking country (e.g., Bion et al., 2006; Rauber, 2006), solely upon production (Baptista, 2006), a limited set of vowels (Souza, 2012), and/or a single proficiency level. By investigating the production and perception of the English vowels by native BP speakers of different proficiency levels living in Victoria, BC, Canada, I have presented new, empirical data on how vowel distinctions are manifested in the interlanguage of these speakers.

In this chapter, further discussion is provided regarding these data presented in Chapters 4 and 5 in light of the study's guiding questions, previous research and theories presented in the literature review, and the pedagogical implications of the study, as well as a discussion of possible future directions for research.

The present chapter is organized into three main subsections. First, a discussion is provided regarding the findings of the study, organized by each of the research questions. Next, the pedagogical implications of the study will be discussed. Finally, possible directions for future research will be discussed.

6.1 Discussion

Guiding this investigation were three sets of questions: one relating to the production of the CE vowels, another relating to perception, and a third relating to the connection between production and perception.

6.1.1 Production. The two questions pertaining specifically to production for this study were:

1. How will the experimental groups' productions–as measured in terms of formant frequencies, vowel durations[11], and Euclidean distances between vowel pairs–of the English L2 vowels (/i, ɪ, e, ɛ, æ, ʌ, ɑ, o, ʊ, u/) differ between the intermediate and advanced learner experimental groups and the native English speaker control group?

2. How will the participants' productions of the L2 vowels compare to their productions of the BP vowels (/i, e, ɛ, a, ɔ, o, u/)?

While Chapter 4 explored these questions with regards to formant frequencies in-depth, a brief review of the findings is presented as a kind of executive summary. It was hypothesized that the intermediate proficiency group would produce the similar L2 vowels (i.e., /i, e, ɛ, o, u/) with formant frequencies close to their BP counterpart, while the advanced participants would produce the similar L2 vowels as an intermediary *between* their BP counterparts and the L1 vowels of the control (i.e., Hypothesis A). It was hypothesized that the new L2 vowels (/ɪ, æ, ʊ, ʌ, ɑ/) would not be acquired by the intermediate learners, instead being conflated with preexisting phonetic categories, while

[11] While it was decided that this study would not investigate the duration of the production in-depth, neither experimental group appeared to use duration as a cue in producing the vowel contrasts of CE.

the advanced group would produce them with formant values similar those of native speakers (i.e., Hypothesis B). However, it was further hypothesized that some new vowels that are too similar to an existing phonetic category will remain persistently difficult to acquire across the proficiency groups, with the existing L1 sound and new L2 sound eventually merging into an intermediary form rather than a new contrast being formed (i.e., Hypothesis C). Table 38 below summarizes the findings in relation to the hypotheses.

Table 38. Summary of Findings Pertaining to Production of the CE Vowels

Hypothesis	Intermediate Group	Advanced Group
A	•Partially confirmed. •L2 /u, o, ɛ/ were found to be phonetically more similar to their BP counterparts than the TL, confirming the hypothesis. •/i, e/ appear to be produced similarly across languages, making it difficult to confirm or reject the hypothesis.	•Partially confirmed. •/u/ was produced at an intermediary point between the BP and TL counterparts, confirming the hypothesis. •/i, e, o/ were shown to be phonetically similar across languages, making confirmation or rejection of the hypothesis difficult.
B	•Confirmed. •The intermediate speakers are unable to distinguish /i/ from /ɪ/, /ɛ/ from /æ/, or /u/ from /ʊ/, confirming the hypothesis.	•Mainly rejected.[12] •While the advanced group showed definite progress over the intermediate group in terms of acquiring the new vowels and producing various contrasts, they were often phonetically dissimilar from the control group, rejecting the hypothesis.
C	•Confirmed •/ʌ/ and /ɑ/ were not assimilated into a preexisting category, but were not proven	•Confirmed •The advanced participants merged the vowel /æ/ with /ɛ/ into an intermediary form, confirming the hypothesis.

[12] While the hypothesis was mainly rejected due to the new vowels not being produced with formant values similar to native speakers, it should be noted that this is not a requirement of the SLM, which would characterize these productions as being demonstrative of the acquisition of new phonetic categories.

	to have been fully acquired by the intermediate group, confirming the hypothesis.	

With regards to previous studies investigating the ability of native speakers of BP to produce various English vowel contrasts, it is possible to observe that the results of this study are largely confirmatory. In the case of Rauber et al. (2005), the authors reported that 56.25% of their participants produced the /ɪ/-/e/ contrast, 50% produced the /i/-/ɪ/ contrast, 18.75% produced "some distinction" between /u/ and /ʊ/, and none produced a distinction between /ɛ/ and /æ/. While the authors unfortunately did not provide an explanation as to how they determined whether a distinction was made between two vowels, their results demonstrate the relative difficulty of producing these contrasts. In other words, the vowel pairs in Rauber et al. (2005), ordered from easiest to hardest to produce, are /ɪ/-/e/ > /i/-/ɪ/ > /u/-/ʊ/>/ɛ/-/æ/), which is the same order exhibited by the advanced participants of the present study.[13]

Rauber (2006) found that the experimental participants were able to produce the vowel contrasts in the following descending order of accuracy: /i/-/ɪ/, /u/-/ʊ/, /ɛ/-/æ/, which is also reflected in the data of the present study. Table 39 below shows the rate of similarity between the male L2 and control participants in Rauber (2006) on the left, and the rate of similarity between the advanced L2 and control participants in the present study on the right.[14] It is worth noting that the participants of the present study performed considerably better in terms of being able to produce EDs that were more similar to the

[13] The participants in Rauber et al. (2005), Bion et al. (2006), and Rauber (2006) were advanced L2 English speakers and so are only compared to the present study's advanced participants.

[14] While Rauber (2006) divided the participants by gender, both groups behaved similarly and so only the males are shown here.

control group, which could be indicative of a possible effect of environment (i.e., the participants of Rauber's study had never lived in an English-speaking environment).

Table 39. Rates of similarity of the Euclidean distance between the vowel pairs produced by the male L2 participants from Rauber (2006) and the Advanced L2 Participants of the Present Study

Vowel Pair	L2 vs. Control Similarity (Rauber, 2006)	Advanced L2 vs. Control Similarity (Present Study)
/i/-/ɪ/	59.5%	60.2 %
/ɛ/-/æ/	19.8%	41.3%
/u/-/ʊ/	25.7%	49.6%

Note. Adapted from "Perception and Production of English vowels by Brazilian EFL speakers," by A. Rauber, 2006, unpublished doctoral dissertation.

6.1.2 Perception. The two questions pertaining specifically to perception for this study were:

1.Concerning CE vowel perception, how accurately will the participants be able to identify the CE vowels in the identification task? How accurately will all participants discriminate the English vowel pairs during the discrimination task?

2. How will the rates of accurate discrimination differ between the two experimental groups and the control group?

In order to mirror the hypotheses pertaining to production, it was hypothesized that L2 vowels that had BP vowel counterparts (/I, e, ɛ, u, o/) would be perceived accurately by both the intermediate and advanced groups, but those L2 vowels (/ɪ, æ, ʊ, ʌ, ɑ/) that did not have BP counterparts would not be perceived well by the intermediate group (i.e., Hypothesis D). However, as was discussed at length in Chapter 5, attempting to analyze the perception of the CE vowels in terms of similar and new phonetic

categories is problematic, as the L2 participants are expected to conflate various CE vowel contrasts. In other words, while the participants might be expected to perform well on an identification test that contained only the similar vowels, testing the perception of all the CE monophthongs together resulted in no clear difference between the perception of similar and new vowels. In that regard, Hypothesis D was largely rejected.

However, while the rejection of the hypothesis indicates that the instruments were not suitable to test the perception of the categories of similar and new vowels, it should not be taken as evidence that the instruments did not accurately measure the participants' perceptual abilities with regards to the CE vowel contrasts. In fact, similar studies have presented findings that are largely confirmatory of the present study's findings. Table 40 compares the findings of two such studies with the present study.

Table 40. Mean Discrimination Rates (%) and SDs (in parentheses) for the English Vowel Pairs in Bion et al. (2006), Rauber et al. (2005), and the Advanced L2 Participants

Vowel Pair	Bion et al. (2006) (*N* = 17)*	Rauber et al. (2005) (*N* = 16)	Advanced L2 Participants (*N* = 6)
/i/-/ɪ/	81	93.8 (2)	87.5 (15.8)
/ɪ/-/e/		87.8 (2)	100 (0)
/ɛ/-/æ/	50	44 (3)	56.3 (10.5)
/u/-/ʊ/		54.3 (3)	83.3 (15.1)
/ʊ/-/ʌ/		71 (4)	85.4 (18.4)
/ʊ/-/o/		85.7 (2)	93.8 (10.5)
/ʌ/-/ɑ/		20.8 (4)	77.1 (25.5)

*Bion et al. (2006) only investigated the /i/-/ɪ/ and /ɛ/-/æ/ contrasts.

Bion et al. (2006) concluded from their study that the /ɛ/-/æ/ is more difficult to master than the /i/-/ɪ/ pair for BP speakers and point out that while two (out of 17) participants had a "native-like" discrimination rate for /i/-/ɪ/ (defined as over 90%), none displayed such an ability with the /ɛ/-/æ/ pair. The same could be said of the present study's findings, with three advanced L2 participants (wholly half) showing a 100% discrimination rate for /i/-/ɪ/, and none accomplishing this feat for /ɛ/-/æ/.

The present study's findings are particularly interesting when compared with those of Rauber et al. (2005). As can be observed in Table 40, the study shares some similarities with the present study's findings (e.g., the /ɛ/-/æ/ is among the most poorly perceived). However, the advanced L2 participants of the present study outperformed the participants of the Rauber et al. study across the board, with the exception of the /i/-/ɪ/ contrast (although it is worth noting the relatively high SDs of the present study and the smaller sample size). As was postulated with regards to the production data and Rauber (2005) above, this could possibly be due to the effect of environment and the exposure of the participants of the current study to an English-speaking environment.

6.1.3 Production vis-à-vis Perception. Two guiding questions were asked in relation to the connection between production and perception:

1. What is the relationship between the production and perception of English vowels by native BP speakers?

2. How does this relationship between production and perception differ between the intermediate learner and advanced learner groups?

It was hypothesized that both groups ability to perceive some of the CE vowel contrasts would outperform their ability to produce them (Hypothesis E). Similarly, it was hypothesized that perception and production would be linked, with poorly discriminated vowel contrasts being poorly produced in the production task (Hypothesis F).

While Hypothesis E and Hypothesis F were largely confirmed for both proficiency groups, the findings indicate that the groups were at different stages of

acquisition, which could be confirmatory of the findings of Baptista (2006). In the case of intermediate group, while the participants taken as a whole appears to be able to perceive some vowel contrasts (e.g., /i/-/ɪ/, /ʊ/-/ʌ/) more accurately than produce them, the generally low rates of discrimination, high levels of variation, and low rates of similarity in ED when compared with the control group (see Table 41) indicate that none of the contrasts have been acquired in a native-like fashion (i.e., following the >90% standard used by Bion et al., 2006). The advanced group, presumably having reached a more advanced stage of acquisition, show a native-like ability to perceive four of the vowel contrasts (see Table 42) and exhibit a greater ability to perceive than produce a majority of the contrasts (as indicated by the L1 vs. L2 discrimination rate similarity being greater than the L1 vs. L2 ED similarity), thereby confirming Hypothesis E.

Table 41. Intermediate Group Mean Discrimination Rates (DR), Similarity to the L1 DRs, Euclidean Distances (ED) Between the CE Vowel Pairs, and Similarity to the L1 EDs

	DR (%)	L1 vs. L2 DR Similarity (%)	ED (Hz)	L1 vs. L2 ED Similarity (%)
/ɛ/-/æ/*	34.4 (18.6)	36.7	36	33
/ʌ/-/æ/*	45.3 (24.9)	45.3	307	53
/u/-/ʊ/	56.3 (27.5)	57.5	161	66.5
/i/-/ɪ/*	56.3 (29.1)	57.5	30	9.7
/ʌ/-/ɑ/*	57.8 (24)	59	321	70
/ʊ/-/ʌ/*	67.2 (22)	73.3	139	57.7
/ʊ/-/o/	68.8 (26.7)	70.3	146	97.3
/ɪ/-/e/	78.1 (21.9)	79.8	117	66.9
/e/-/ɛ/	82.8 (19.9)	84.6	290	77.9
/o/-/ɑ/	84.4 (17.3)	86.2	189	94.7

*Vowel pairs which displayed a ED that was significantly different ($p<.05$) from the control group.

Table 42. Advanced Group Mean Discrimination Rates (DR), Similarity to the L1 DRs, Euclidean Distances (ED) Between the CE Vowel Pairs, and Similarity to the L1 EDs

	DR (%)	L1 vs. L2 DR Similarity (%)	ED (Hz)	L1 vs. L2 ED Similarity (%)
/ɛ/-/æ/*	56.3 (10.5)	60	45	41.3
/ʌ/-/æ/	75 (17.7)	75	193	85
/ʌ/-/ɑ/*	77.1 (25.5)	78.8	73.7	73.7
/u/-/ʊ/*	83.3 (15.1)	85.1	120	49.6
/ʊ/-/ʌ/	85.4 (18.4)	93.1	242	57.4
/i/-/ɪ/*	87.5 (15.8)	89.4	185	60.2
/o/-/ɑ/	91.7 (10.2)	93.7	178	99.4
/ʊ/-/o/	93.8 (10.5)	95.8	210	67.6
/e/-/ɛ/	97.9 (5.1)	100	349	93.8
/ɪ/-/e/	100 (0)	100	118	67.4

*Vowel pairs which displayed a ED that was significantly different ($p<.05$) from the control group.

The findings of the present study pertaining to the connection between production and perception are in line with previous studies (i.e., Bion et al., 2006; Rauber, 2006; Rauber et al., 2005). Bion et al. (2006) found that the most difficult contrast to perceive (i.e., /ɛ/-/æ/) was also the most difficult to produce and that accurate perception appeared to precede accurate production, as only participants with high rates of discrimination (>75%) were able to produce EDs of over 150Hz for the two vowel pairs investigated. Both Rauber et al. (2005) and Rauber (2006) also concluded that there exists a connection between accurate perception and accurate production, and that the former appears to be a prerequisite for the latter.

6.2 Pedagogical Implications

Taking into account the data and analyses presented in the present study, it is apparent that native speakers of BP learning English have difficulty in accurately perceiving and producing the various vowel contrasts of English. Furthermore, while there appears to be learning taking place (perhaps facilitated by the L2 environment) between the intermediate and advanced group, as evidenced by improved performance on perception tasks and EDs that are more similar to those of the control group, many contrasts appear persistently difficult to acquire and native-like levels of proficiency (i.e., discrimination rates >90%) are not attained for the majority of the contrasts. While the SLM predicts that the acquisition of new L2 sounds should remain possible across the lifespan, it also makes the point that this acquisition is influenced by the nature of the input received, but even the advanced group had difficulty with certain contrasts. Keeping this in mind, it is possible that explicit pronunciation instruction could be beneficial for learners hoping to establish phonetic categories for new L2 vowels (Akahane-Yamada, 1996; Strange & Dittmann, 1984).

However, given that the participants of this study conflate various contrasts and given that EFL/ESL instructors have a limited amount of time to dedicate to pronunciation instruction, it is important to consider which contrasts should be explicitly taught. In consideration of this issue, Brown (1988) utilized the notion of *functional load* (i.e., the measure of the work which phonemes do contrasting lexical items) in order to determine which commonly conflated vowel pairs were more important and therefore more worthy of explicit instruction. For example, Brown, in a rank ordering of commonly

conflated phoneme pairs[15], determined that the /ʌ/-/æ/ pair carries a relatively high functional load (i.e., there exist many minimal pairs between the vowels in English, such as "run" and "ran", or "fun" and "fan")–being assigned a rank of 10– and should therefore be given priority over vowel pairs that carry lower functional loads, such as /i/-/ɪ/ (rank 8, e.g., "sheep" and "ship").

Another possible method for selecting which contrasts to teach would be to provide explicit instruction on those contrasts that appear to remain consistently difficult to acquire across proficiency groups and irrespective of other factors. For example, whereas the /ɛ/-/æ/ pair may carry a relatively low functional load, the difficulty that participants have in acquiring the contrast could make it a good candidate for explicit pronunciation instruction. Meanwhile, a vowel pair such as /i/-/ɪ/ may carry a higher functional load, but the results of this study indicate a progression towards acquisition, with the advanced group displaying a nearly native-like ability to perceive on the contrast on average. Therefore, learners could be expected to acquire the contrast without the need of explicit instruction, while the instructors focus on more difficult–or more marked–contrasts (Cardoso & Collins, 2016).

However, there remains the question of whether L2 learners of English would benefit more from explicit instruction on the production of CE vowel phonemes or from explicit instruction on the perception of these vowel phonemes. The Comprehensible Input Hypothesis (Krashen, 1985) would postulate that providing comprehensible input and thereby emphasizing accurate perception would be the most important source of L2 learning. While the participants' inability to acquire all of the CE vowels after being

[15] The phoneme pairs identified by Brown (1988) were from Received Pronunciation (RP) and not CE, although there exist many similarities between the two and the concept remains valid.

immersed in an English-speaking environment could be taken as evidence that comprehensible input alone may not be adequate, it should be kept in mind that the LoR of the participants was generally low, with the intermediate group's LoRs ranging from two months to 2.6 years. The Pushed Output Hypothesis (Swain, 1985) could provide a possible solution, as it predicts that successful acquisition relies upon producing the target language and is especially successful when the interlocutor does not understand the learner's production and push for understanding. In the case of the CE vowel contrasts, it is possible that learners are not typically misunderstood when conflating the contrasts (especially those with low functional loads), which results in nobody ever pushing them to draw attention to their production, which could possibly facilitate acquisition, as is predicted by the Noticing Hypothesis (Schmidt, 1995).

When discussing the acquisition of foreign speech sounds, it should be noted that whether someone possesses "nativelike" pronunciation abilities should not necessarily be the only measure of a learner's success. While accented speech could entail negative consequences (e.g., negative evaluation), the lofty goal of having no discernible foreign accent is perhaps unrealistic for many, especially those who began learning an L2 at a later age (Flege, Munro, & Mackay, 1995). Rather, *intelligibility*–defined by Munro and Derwing (1995) as " the degree to which a speaker's utterance is actually understood by a listener"–could be a more appropriate means of assessing the communicative competence of an L2 learner (Munro, 2008; Subtelny, 1997).

Finally, while this section has attempted to explore the possible pedagogical implications of the present study, it does not seek to provide practical instruction for

educators. Please see Bradlow (2008) and VanPatten (2002) for more research in this regard.

6.3 Limitations and Future Directions

Ultimately, the limitations of this study should be taken into consideration when interpreting its findings. The most notable of these limitations is perhaps the relatively small sample size, which led to a high level of variation in some tasks. Furthermore, while the IELTS speaking test was shown to be a valid and reliable means of assessing proficiency–as evidenced by the groups' performances on the production and perception tasks–it would perhaps be beneficial to control for the variables of length of residence (LoR), age of onset of acquisition (AOA), and/or hours of input (HoI). However, it should be kept in mind that controlling for all of these variables and finding a larger population might not be feasible unless the study were conducted somewhere with a larger population of native BP speakers (e.g., Miami, USA).

As a suggestion for future research, it would be interesting to conduct a study that measured the effects of explicit pronunciation instructions with regards to the vowel contrasts that appear to remain persistently difficult to perceive and produce accurately across proficiency groups and studies (e.g., Rauber, 2006), most notably /ɛ/-/æ/.

6.4 Concluding Remarks

In this chapter, I have summarized the present study by providing a discussion of its findings with regards to its guiding questions and hypotheses and the findings of previous research. Furthermore, some pedagogical implications of these findings were

presented. Finally, I have briefly discussed the limitations of the study, as well as some suggestions for future research.

In sum, the present thesis has sought to investigate the production and perception of the CE vowels by native speakers of BP living in Victoria, BC, Canada. To that end, it has been successful in providing new empirical data for use in future studies. Furthermore, in investigating the acquisition of these L2 vowels, this study has demonstrated that learners may show a greater ability to acquire phonetic distinctions than the populations of previous studies (e.g., Rauber, 2006), possibly due to the more optimal input afforded by an English-speaking environment, among other individual learner variables.

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Appendix

Appendix A

Background Information Questionnaire

This is a background questionnaire to select participants for a study on the production and perception of English vowels by speakers learning English as a second language. Your name, e-mail address, and personal information will be kept confidential. Thank you very much for your time.

Date: _____/_____/_____

Name:_____	Gender: ☐Male ☐Female
E-Mail Address:_____	Age:_____
Place of Birth:_____	Profession:_____

1. What is the highest level of education you have completed? Please list certificates or degrees that you received.

2. Do you have any special linguistic qualifications? For example: Are you a translator or interpreter, a foreign language teacher, or anything of that kind?

3. What language did you learn first?

4. What language did you grow up speaking, if different from (3)?

5. Where did you grow up, if different from your place of birth?

6. What was the first foreign language that you learned, and at what age did you learn it?

7. At what age did you have your first contact with English?

8. What major variety or dialect of English are you most familiar with (i.e. British English, Canadian English, etc.)

9. For how long have you been learning English?

10. What countries have you stayed or lived in where English is spoken, and how long did you stay in each one of them?

11. Please list the languages that you have learned, with the age that each was learned and indicate how well you can speak these languages now (by giving a number from 1 to 5 where 1 means "poor" and 5 means "native-like").

Language	Age	Level
		speaking___, listening___, reading___, writing___
		speaking___, listening___, reading___, writing___
		speaking___, listening___, reading___, writing___
		speaking___, listening___, reading___, writing___

12. For how long have you been in Canada?

13. How many hours per day do you speak with people who are fluent English speakers?

14. Do you have any hearing loss, or any other kind of impairment affecting your hearing?

15. Have you taken any of the following proficiency tests? If not, please mark "N/A," and, if yes, please provide the score(s) and the year you took the test.

Test	Score	Year
TOEFL (Test of English as a Foreign Language)		
MELAB (Michigan English Language Assessment Battery)		
IELTS (International English Language Testing System)		
Other		

Appendix B

IELTS Speaking Test Prompts

Speaking Test Part 1: Questions

Let's talk about your hometown or village:

- What kind of place is it?
- What's the most interesting part of your town/village?
- What kind of jobs do the people in your town/village do?
- Would you say it's a good place to live? (Why?)

Let's move on to talk about accommodation:

- Tell me about the kind of accommodation you live in?
- How long have you lived there?
- What do you like about living there?
- What sort of accommodation would you most like to live in?

Speaking test part 2: candidate task card
Describe something you own which is very important to you.

You should say:

- Where you got it from
- How long you have had it
- What you use it for; and
- Explain why it is important to you.

You will have to talk about the topic for 1 to 2 minutes.

You have one minute to think about what you're going to say.

You can make some notes to help you if you wish.

Rounding off questions

Tell me

- Is it valuable in terms of money?
- Would it be easy to replace?

Part 3: Follow-Up Questions

Let's consider first of all how people's values have changed.

- What kinds of things give status to people in your country?
- Have things changed since your parents' time?

Finally, let's talk about the role of advertising.

- Do you think advertising influences what people buy?

Appendix C

IELTS Speaking Band Descriptors

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IELTS Speaking band descriptors (public version)

Band	Fluency and Coherence	Lexical Resource	Lexical Resource	Pronunciation
9	▪ speaks fluently with only rare repetition or self correction; any hesitation is content-related rather than to find words or grammar ▪ speaks coherently with fully appropriate cohesive features ▪ develops topics fully and appropriately	▪ uses vocabulary with full flexibility and precision in all topics ▪ uses idiomatic language naturally and accurately	▪ uses a full range of structures naturally and appropriately ▪ produces consistently accurate structures apart from 'slips' characteristic of native speaker speech	▪ uses a full range of pronunciation features with precision and subtlety ▪ sustains flexible use of features throughout ▪ is effortless to understand
8	▪ speaks fluently with only occasional repetition or self-correction; hesitation is usually content-related and only rarely to search for language ▪ develops topics coherently and appropriately	▪ uses a wide vocabulary resource readily and flexibly to convey precise meaning ▪ uses less common and idiomatic vocabulary skilfully, with occasional inaccuracies ▪ uses paraphrase effectively as required	▪ uses a wide range of structures flexibly ▪ produces a majority of error-free sentences with only very occasional inappropriacies or basic/non-systematic errors	▪ uses a wide range of pronunciation features ▪ sustains flexible use of features, with only occasional lapses ▪ is easy to understand throughout; L1 accent has minimal effect on intelligibility
7	▪ speaks at length without noticeable effort or loss of coherence ▪ may demonstrate language-related hesitation at times, or some repetition and/or self-correction ▪ uses a range of connectives and discourse markers with some flexibility	▪ uses vocabulary resource flexibly to discuss a variety of topics ▪ uses some less common and idiomatic vocabulary and shows some awareness of style and collocation, with some inappropriate choices ▪ uses paraphrase effectively	▪ uses a range of complex structures with some flexibility ▪ frequently produces error-free sentences, though some grammatical mistakes persist	▪ shows all the positive features of Band 6 and some, but not all, of the positive features of Band 8
6	▪ is willing to speak at length, though may lose coherence at times due to occasional repetition, self-correction or hesitation ▪ uses a range of connectives and discourse markers but not always appropriately	▪ has a wide enough vocabulary to discuss topics at length and make meaning clear in spite of inappropriacies ▪ generally paraphrases successfully	▪ uses a mix of simple and complex structures, but with limited flexibility ▪ may make frequent mistakes with complex structures, though these rarely cause comprehension problems	▪ uses a range of pronunciation features with mixed control ▪ shows some effective use of features but this is not sustained ▪ can generally be understood throughout, though mispronunciation of individual words or sounds reduces clarity at times

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5	▪ usually maintains flow of speech but uses repetition, self-correction and/or slow speech to keep going ▪ may over-use certain connectives and discourse markers ▪ produces simple speech fluently, but more complex communication causes fluency problems	▪ manages to talk about familiar and unfamiliar topics but uses vocabulary with limited flexibility ▪ attempts to use paraphrase but with mixed success	▪ produces basic sentence forms with reasonable accuracy ▪ uses a limited range of more complex structures, but these usually contain errors and may cause some comprehension problems	▪ shows all the positive features of Band 4 and some, but not all, of the positive features of Band 6
4	▪ cannot respond without noticeable pauses and may speak slowly, with frequent repetition and self-correction ▪ links basic sentences but with repetitious use of simple connectives and some breakdowns in coherence	▪ is able to talk about familiar topics but can only convey basic meaning on unfamiliar topics and makes frequent errors in word choice ▪ rarely attempts paraphrase	▪ produces basic sentence forms and some correct simple sentences but subordinate structures are rare ▪ errors are frequent and may lead to misunderstanding	▪ uses a limited range of pronunciation features ▪ attempts to control features but lapses are frequent ▪ mispronunciations are frequent and cause some difficulty for the listener
3	▪ speaks with long pauses ▪ has limited ability to link simple sentences ▪ gives only simple responses and is frequently unable to convey basic message	▪ uses simple vocabulary to convey personal information ▪ has insufficient vocabulary for less familiar topics	▪ attempts basic sentence forms but with limited success, or relies on apparently memorised utterances ▪ makes numerous errors except in memorised expressions	▪ shows some of the features of Band 2 and some, but not all, of the positive features of Band 4
2	▪ pauses lengthily before most words ▪ little communication possible	▪ only produces isolated words or memorised utterances	▪ cannot produce basic sentence forms	▪ speech is often unintelligible
1	▪ no communication possible ▪ no rateable language			
0	▪ does not attend			

Appendix D

Corpus for Elicitation of English Vowel Tokens

Instructions: Please read each phrase carefully in your natural speaking voice. Pause for a few seconds in between each phrase.

1. Peak and Pete sound like seat.
2. Shot and pot sound like sot.
3. Tet and tech sound like kept.
4. Took and put sound like soot.
5. Tat and tack sound like cat.
6. Tot and tock sound like cot.
7. Coat and poach sound like soak.
8. Kate and pate sound like sate.
9. Cat and pat sound like sat.
10. Put and took sound like cook.
11. Tote and toke sound like coat.
12. Kept and pet sound like set.
13. Fit and pit sound like sit.
14. Tate and take sound like Kate.
15. Cut and putt sound like shut.
16. Tit and tick sound like kit.
17. Shoot and poop sound like suit.
18. Tut and tuck sound like cut.
19. Teat and teak sound like keep.
20. Toot and tuke sound like coot.

Appendix E

Corpus for Elicitation of BP Vowel Tokens

Em tique e tico temos i.

Em cóque e cóco temos ó.

Em quique e quico temos i.

Em pôpe e pôpo temos ô.

Em fáfe e fáfo temos a.

Em téque e téco temos é.

Em pépe e pépo temos é.

Em sôsse e sôsso temos ô.

Em fufe e fufo temos u.

Em cáque e cáco temos a.

Em pópe e pópo temos ó.

Em côque e côco temos ô.

Em pápe e pápo temos a.

Em sósse e sósso temos ó.

Em quêque e quêco temos ê.

Em pipe e pipo temos i.

Em sásse e sásso temos a.

Em pêpe e pêpo temos ê.

Em pupe e pupo temos u.

Em táque e táco temos a.

Em susse e susso temos u.

Em cuque e cuco temos u.

Em fife e fifo temos i.

Em fófe e fófo temos ó.

Em quéque e quéco temos é.

Em têque e têco temos ê.

Em tóque e tóco temos ó.

Em fêfe e fêfo temos ê.

Em sésse e sésso temos é.

Em fôfe e fôfo temos ô.

Em tôque e tôco temos ô.

Em sisse e sisso temos i.

Em tuque e tuco temos u.

Em féfe e féfo temos é.

Appendix F

Identification Test Stimuli

/i/	/ɪ/	/e/	/ɛ/	/æ/
Keep	Fit	Fate	Pet	Cat
Peak	Pit	Kate	Set	Pat
Seat	Sit	Take	Tech	Sat
/ʌ/	**/ɑ/**	**/o/**	**/ʊ/**	**/u/**
Cut	Cot	Coat	Cook	Shoot
Putt	Pot	Poke	Put	Suit
Tuck	Tot	Soak	Took	Tuke

Appendix G

Discrimination Test Triads

A. /i/-/ɪ/
1. peat, seat, **kit**
2. **pit**, keep, seep
3. peat, **tit**, seat
4. teak, seek, **sit**
5. pit, sit, **keep**
6. **peak**, kip, sip
7. pit, **teak**, sit
8. tit, hit, **seek**

B. /ɪ/-/e/
1. kit, pit, **kate**
2. **pate**, sit, tit
3. tit, **sate**, sip
4. fit, hit, **take**
5. Tate, fate, **fit**
6. **pit**, pate, sate
7. sate, **sit**, late
8. Kate, pate, **tit**

C. /e/-/ɛ/
1. Kate, pate, **pet**
2. **set**, sate, tate
3. fate, **tet**, take
4. pate, kate, **tech**
5. pet, set, **sate**
6. **pate**, tech, pet
7. set, **fate,** pep
8. pep, tech, **take**

D. /ɛ/-/æ/
1. pet, set, **sat**
2. **pat**, pep, tet
3. tech, **cat**, set
4. tet, pet, **tack**
5. pat, sat, **pet**
6. **set**, cat, pat
7. cat, **tet**, sat
8. pat, cat, **pep**

E. /u/-/ʊ/
1. shoot, toot, **took**
2. **put**, shoot, poop
3. tuke, **soot**, coot
4. toot, coot, **cook**
5. took, soot, **toot**
6. **shoot**, put, cook
7. took, **tuke**, cook
8. soot, put, **coot**

F. /ʊ/-/o/
1. cook, took, **coat**
2. **tote**, put, soot
3. soot, **toke**, took
4. cook, soot, **soak**
5. tote, coat, **took**
6. **cook**, soak, toke
7. poke, **soot**, soak
8. tote, poke, **put**

G. /o/-/ɑ/
1. coat, tote, **cot**
2. **cot**, soak, toke
3. poke, **sot**, soak
4. coat, tote, **tot**
5. cot, tot, **tote**
6. **coat**, sot, cot
7. cot, **soak**, tot
8. tot, cot, **toke**

H. /ʊ/-/ʌ/
1. cook, took, **cut**
2. **putt**, soot, put
3. took, **shut**, soot
4. soot, cook, **tuck**
5. putt, shut, **put**
6. **took**, cut, putt
7. tut, **cook**, putt
8. cut, shut, **soot**

I. /ʌ/-/ɑ/
1. putt, shut, **pot**
2. **sot**, tuck, shut
3. tut, **tot,** putt
4. shut, cut, **cot**
5. pot, cot, **putt**
6. **cut**, tot, sot
7. tot, **tuck**, pot
8. cot, sot, **shut**

J. /ʌ/-/æ/
1. putt, shut, **pat**
2. **sat**, cut, tuck
3. tuck, **tack**, shut
4. cut, tuck, **cat**
5. pat, tack, **putt**
6. **shut,** sat, pat
7. tack, **cut**, cat
8. sat, tack, **tuck**

/i/
1. seat, teak, keep
2. peat, keep, seep
3. seek, peat, peak
4. peak, seek, keep

/ɪ/
1. tit, pit, kip
2. kip, fit, tit
3. sit, kit, sip
4. pit, hit, sit

/e/
1. Kate, tate, sate
2. sate, fate, take
3. take, fate, sate
4. pate, sate, Kate

/ɛ/
1. pet, set, tet
2. set, tech, pep
3. tet, pep, set
4. tet, set, pet

/æ/
1. sat, pat, cat
2. cat, sat, pat
3. tack, pat, cat
4. pat, tack, sat

/u/
1. shoot, toot, poop
2. tuke, coot, toot
3. tuke, shoot, poop
4. poop, tuke, coot

/ʊ/
1. took, put, soot
2. cook, soot, took
3. soot, took, cook
4. put, cook, soot

/o/
1. coat, tote, toke
2. toke, soak, coat
3. soak, poke, tote
4. poke, soak, coat

/ɑ/
1. sot, pot, cot
2. tot, cot, pot
3. cot, tot, shot
4. shot, cot, tot

/ʌ/
1. cut, putt, shut
2. tuck, shut, putt
3. putt, cut, shut
4. shut, putt, cut