8-2021

Vowel Intelligibility of Salvadoran-Accented English Vowels in Running Speech

Oscar Martinez Diaz

Vowel Intelligibility of Salvadoran-Accented English Vowels in Running Speech

by

Oscar Armando Martinez Diaz

A Thesis

Submitted to the Graduate Faculty of

St. Cloud State University

in Partial Fulfillment of the Requirements

for the Degree of

Master of Arts in

English: Teaching English as a Second Language

August, 2021

Thesis Committee:
Ettien Koffi, Chairperson
Edward Sadrai
Joy McKenzie

Abstract

This study focuses on English in El Salvador, which is a country located in Central America, and it presents information about the production of Salvadoran-accented English vowels by speakers of English in this country. Peña (2019) started studying Salvadoran-accented vowels in isolation. For this study, the vowels in running speech are analyzed. The participants of this study include English speakers from El Salvador. The information of Salvadoran-accented vowels, including the formats F0, F1, F2, F3, duration, and intensity, is compiled in this study. The focus of the study is to assess intelligibility levels within Salvadoran-accented vowels in running speech and to compare them with those produced by a native English speaker. For this study, 5775 tokens were utilized. F1 receives most of the attention because it plays a disproportionate role in intelligibility. According to Ladefoged and Johnson (2015, p. 207), it controls 80% of the acoustic energy in vowels. Second, F2 is measured and analyzed because it gives precise information about the tongue movement in the production of vowels. Data analysis was also conducted for the rest of the correlates because they also contribute to getting an accurate representation of Salvadoran-accented vowels that can help determine how each vowel is pronounced. Data shows that Salvadorans have intelligibility issues with the *kiss* vowel [ɪ], the *goat* vowel [o], and the *trap* vowel [æ]. This study also provides the readers with conclusions and pedagogical implications for ESL/EFL teachers and researchers working with Salvadoran learners.

Acknowledgment

First and foremost, I want to express gratitude to God for this achievement. He has not abandoned me in the 2 years I have been at St. Cloud State University. Although the whole world has been through a pandemic during 2020 and part of 2021 (COVID-19), I want to thank St. Cloud State University for the support provided to the faculty and students of the MA TESOL program. I would also like to thank the TESL faculty of SCSU led by Dr. Robinson for giving me the resources to complete my master's program. My appreciation goes to Dr. Schwartz for supporting me as a teacher in his Intensive English Program and the English for Academic Purposes program.

I am grateful to my thesis committee members: Professor Joy McKenzie for her insights as a Speech Language Pathologist; Dr. Edward Sadrai for his class on theories of Second Language Acquisition and constant support; Dr. Koffi for his patience, constant support, and academic coaching in writing. You supported me through every step I took while writing my thesis with patience and attention to details. Words cannot describe how grateful I am to you.

I am thankful to my beloved mother, Ana Gloria Diaz for her support throughout my academic life in El Salvador. I would not be here without you. I know this will make you proud. To my wife, Cristina Montano, for your unconditional love, support, and patience. I am counting the hours until I get back and can be with you and our daughter (Alejandra Martinez). I am also thankful to Marta Carranza, Fernando Herrera, and Juan Rodriguez from Education USA and the American Embassy in El Salvador who made it possible for me to come to the US to complete this degree.

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Chapter I: Introduction

Chapter Introduction

English is taught as a foreign language in El Salvador, and it is by far the most prevalent foreign language there. Both public and private institutions include it as part of their programs. In El Salvador, the native language is Spanish, and there are very few native English speakers. As a result, interaction with native speakers is almost impossible, and when it occurs, there are intelligibility issues. Vowels are crucial in intelligibility because they are what listeners rely on when trying to understand someone else's speech. According to Ladefoged (2006), accents of English differ more in the use of vowels than in the use of consonants. That is why the study of vowels is so important to measure and address intelligibility. This research deals with the production of vowels in running speech by Salvadoran English speakers.

Studying vowels is important because they carry more weight in intelligibility than do consonants (Fletcher, 1953, p. 418). The information collected in this research provides information related to the specific vowels that cause intelligibility issues for Salvadoran speakers of English so that intelligibility can be improved and addressed properly to promote better communication with other speakers of English.

This research includes the following chapters: introduction, internal masking analysis, external masking analysis, pedagogical implications and applications, and additional insights into Salvadoran-spoken English. First, the introduction chapter contains a literature review with important information for the study and the methodology that was followed in this thesis. Second, the internal masking chapter includes an intelligibility assessment of the vowels produced by the Salvadoran participants. Third, the external masking analysis comprises an intelligibility assessment of Salvadoran-accented vowels compared to native English vowels.

Forth, pedagogical implications and applications are the focus of Chapter IV. It proposes different steps to address specific intelligibility issues. All the data that is not included in the intelligibility analysis is included in Chapter V. Finally, the thesis includes an appendix section where all relevant documents and measurements are listed.

Literature Review

The focus of this study is necessarily to measure intelligibility of vowels as they highlight many features which are unique to English and potentially difficult for native speakers of other languages. Ladefoged (2006) scores that "accents of English differ more in their use of vowels than in their use of consonants" (p. 38). This study focuses on running speech to capture a more realistic, everyday classroom type of speech. It is necessary to note that this study does not include all the English vowels, as the *foot* vowel [ʊ] is not included. Salvadorans, much as English speakers from other countries, try to sound like Americans because in the TESOL business, companies hire Americans to teach English. If Salvadorans sound like Americans, they have better chances of being hired by companies.

English in El Salvador

According to Education First (2020) in their English Proficiency Index, El Salvador ranks in the 56th place among the 100 countries listed. El Salvador is said to have a low proficiency based on the results of the Standard English Test. However, it is encouraging to know that it is one of the countries which reports one of the highest rates of growth, rising 2.63 points from 2018 to 2019. Because El Salvador is a country in the expanding circle (a list of countries in which English has no special administrative status but is recognized as a lingua franca), citizens of that country have social and economic motivators to learn English. In El Salvador, English is a language in education since it is taught as an individual course in the curriculum. Globalization is influencing several countries around the world, and El Salvador is not an exception. As a result, the number of Salvadoran citizens learning English as a foreign language increases every year. Some Salvadorans receive English as a class when they are children, but this is mostly the case in private and/or bilingual schools, not most schools in the country.

In the case of public schools, students receive EFL classes for only 5 years (seventh – eleventh grade) and only 5 hours a week. The quality of the classes is unsatisfactory, and students do not learn the basics of the language in the 5 years. Martinez (2015), in an investigation conducted in 22 public schools in El Salvador, found that the way classes are designed does not lead to effective learning. As a result, English learners in public schools do not develop any of the four macro skills (reading, speaking, writing, and listening) as classes tend to focus on translating paragraphs and articles. That is one of the main reasons why, to learn another language and improve their résumé, Salvadoran students seek language academies to learn English. Learning English is also possible in other institutions such as universities and technical and community colleges.

In El Salvador, English classes are taught in Spanish. In the General Law of Education of El Salvador (Asamblea Legislativa de la República de El Salvador, 1990), Legislators address the existence of Nonformal Education, which would include language academies, and clearly state that they (nonformal institutions) "*podran estar a cargo de entidades estatales o privadas… y No estaran sujeta a controles estatales*." [can be governmental or private… and they will not be bound to governmental controls] (p. 12). This implies that there is no control over the curriculum English academies and most universities teach.

Having clarified that language academies, which handle most of the English learning population, are subject to no regulations regarding curriculum or any other type of educational regulations, it can be presumed that each institution can teach in any way they deem adequate. Interestingly, the trend is that most language academies pride themselves on teaching through a communicative approach, since communication is most people's goal. The main objective of most Salvadorans learning English is to be able to speak English and sound like Americans. This means that they try to imitate the sounds produced by Americans to avoid "having an accent" while speaking English. Not having an accent should not be that critical since there are numerous accents in the United States and in the world.

The main purpose of this study is to complement the study of Peña (2019), using acoustic phonetics methodology to help Salvadorans learning English to identify which vowels are most likely problematic. This study deals with vowels in running speech. Peña carried out a study of Salvadoran-accented vowels in isolation; the participants were Salvadoran teachers who volunteered to be recorded while reading different words containing the vowel sounds.

Peterson and Barney (1952) point out that the perception and production of vowel sounds can be influenced by speakers and listeners' backgrounds.

> In the elementary case of a word containing a consonant-vowel-consonant phoneme structure, a speaker's pronunciation of the vowel within the word will be influenced by his particular dialectal background; and his pronunciation of the vowel may differ both in phonetic quality and in measurable characteristics from that produced in the word by speakers with other backgrounds. (p. 175)

Conclusions can be drawn to affirm that the native language of the speaker may influence the production of the vowel sound in English. That is why English native speakers can identify when an English speaker has "an accent". This also happens with other dialects and variations of English. As an example, a native English speaker from Texas speaks in a different way than a native English speaker from Minnesota. These differences vary in measurable characteristics, which means that it is possible to identify the differences if they are analyzed acoustically. At the same time, differences among dialects can be contrasted to assess intelligibility.

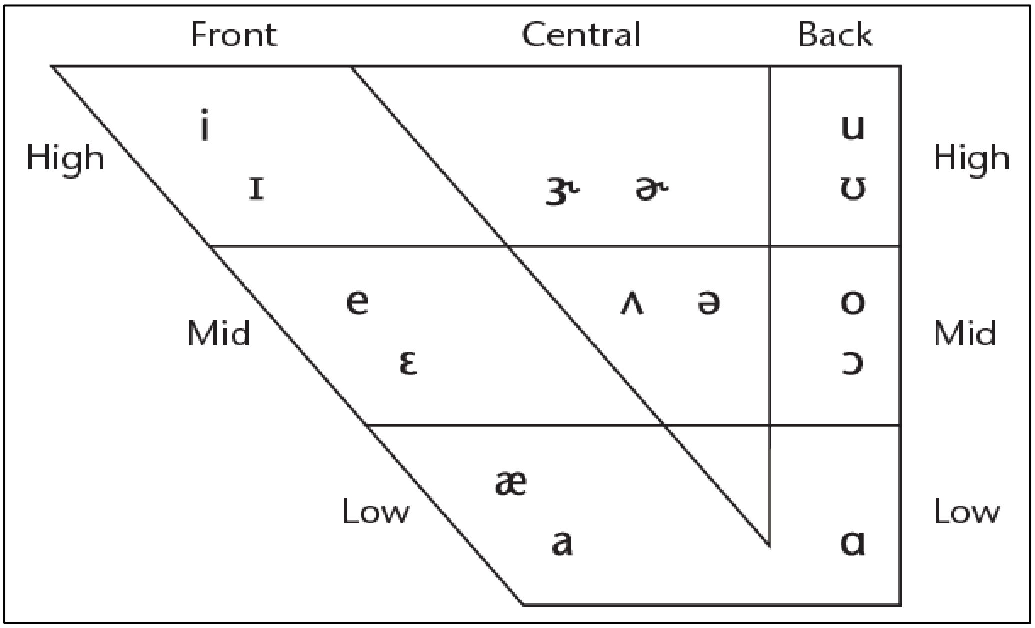
General American English Vowels

The first known method for measuring the production of vowels can be attributed to Peterson and Barney (1952). They designed a list of ten monosyllabic words beginning with [h] and ending with [d], the words differing only in one vowel. The words that they used were *heed*, *hid, head, had, hod, hawed, hood, who'd,* and *hud*. In their study, Peterson and Barney (1952) considered a total of 76 participants, including 33 men, 28 women, and 15 children. They conducted an analysis in which a group of 70 observers had to identify the vowels they heard, and they collected data on the number of agreements in identifying each of the vowels.

General American English is considered to have a repertoire of 11 vowels. The list of vowels includes /i/, /ɪ/, /e/, /ɛ/, /æ/, /ɑ/, /o/, /ɔ/, /ʊ/, /u/, and /ʌ/. In this study, the letter vowel /ɚ/ is included in the analysis. The following vowel space illustration (Figure 1.1) provides a graphical representation of those vowels, showing where vowels are in the acoustic and articulatory space. The picture shows an acoustic vowel space based on the first two formants for vowels (F1 represents shows vowel height and F2 represents mouth aperture). Formants are the bands of energy that correspond to the resonances of the vocal tract for particular shapes. The vertical axis represents the frequency of the first formant (F1). The horizontal axis shows the frequency gap between the first two formants (F2-F1). Figure 1.1 presents a 2-dimensional representation that corresponds to tongue position, with indications of high vs. low and front vs. back positions.

Figure 1.1

Classification of American English Vowels (Shaffer & Kutz, 1973)

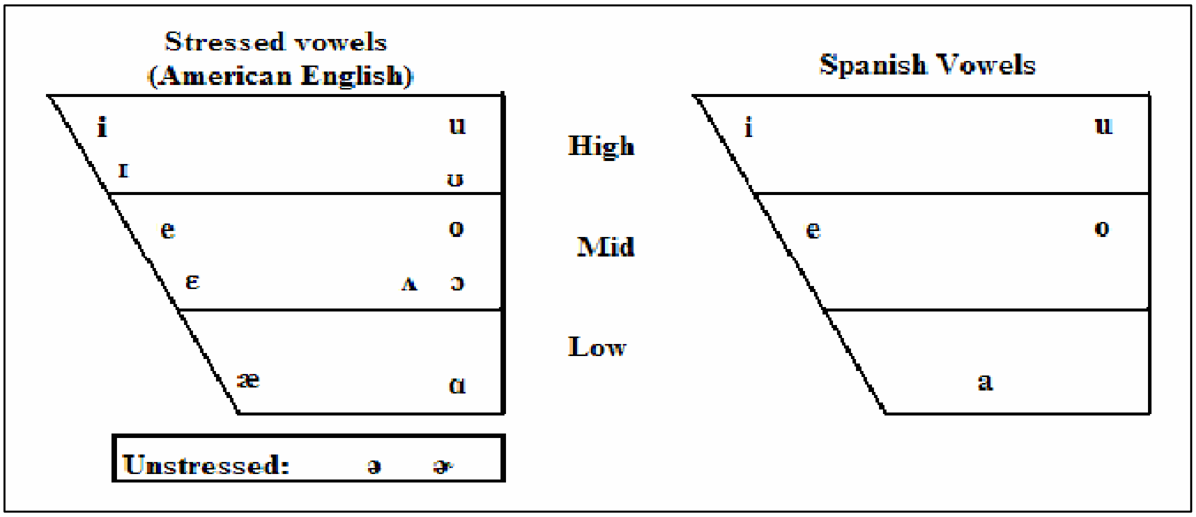


Spanish Vowels

Germanic origin of English, it may represent a challenge for Spanish speakers because Spanish is a Romance language and part of the Indo-European language family. In terms of its origin, Spanish is closer to French, Italian, and Portuguese because they are also Romance languages, although the vowel systems of all the languages are different. Because of some sounds in English do not exist in Spanish. According to Coe (1987), Spanish speakers find English pronunciation hard because Spanish has only five vowel sounds, and English has 13 vowel sounds. Figure 1.2 presents the vowel systems of American English and Spanish.

Figure 1.1

Vowel Systems of American English and Spanish (adapted from Whitley, 2002, p. 28)



Assessing Intelligibility

To be able to assess intelligibility is not only about being able to identify an accent or being able to tell when someone sounds different. According to Koffi (2017, p. 281), "A listener's own linguistic background will strongly influence his judgments about any speech which he hears". In other words, the judgment of any English native speaker will be compromised by his or her own background. Apart from the methodology described before, Koffi (2012) presents an alternative methodology that relies on Instrumental Acoustic Phonetic analysis. Koffi states that the methodology he uses in his paper to assess the intelligibility of speakers of English has been labeled as 'instrumental' because it does not rely on human agency to assess intelligibility, but rather on acoustic devices and techniques. An instrumental methodology to assess intelligibility is also suggested by Ladefoged, (2003) because "instrumental phonetics has made it possible to document descriptions of languages more precisely" (p. 30).

Formants provide relevant acoustic information in the production of vowels. F1 shows a vowel's height, F2 shows backness, and F3 shows lip rounding. According to Ladefoged (2006), F1 is the most relevant correlate in differentiating vowels since it contains 80% of the energy in the vowel; F2 is not as important in this role (p. 188). Using Peterson and Barney's (1952) and Hillenbrand et al.'s (1994) methodology, one can measure vowel intelligibility acoustically. Unintelligibility is also called masking; it takes place when the F1 distance between two vowel phonemes is less than 60 Hz. Koffi (2021, p. 75) presents the various levels of masking that may take place. Table 1.1 presents the acoustic distance and intelligibility measurements that are used in this thesis.

Table 1.1

Relative Functional Load and Intelligibility Matrix

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

Catford (1987) explains Relative Functional Load (RFL) is "... the functional load of a phoneme or phonemic contrast is represented by the number of words in which it occurs in the lexicon, or in the case of a phonemic contrast, the number of pairs of words in the lexicon that serves to it keep distinct" (p. 88). According to Koffi (2021), it is possible to identify four distinct levels of intelligibility based on the Relative Functional Load. Table 1.2 presents the relative functional load and intelligibility measurements that are used in this thesis (Koffi, 2021, p. 50).

Table 1.2

Relative Functional Load and Intelligibility Ranges

No.	RFL	Intelligibility Rating
1.	0 - 24%	Good intelligibility
2.	25 - 49%	Fair intelligibility
3.	50 - 74%	Mediocre intelligibility
4.	75 - 100%	Poor intelligibility

Studies on L2 Accented English Vowels

In recent years, different researchers have conducted acoustic analyses taking different languages as references. The following section of this literature review contains an overview of the most relevant ones.

Spanish Speakers. In 2012, Giacomino conducted a study to assess the production of English vowels of L1 Spanish speakers. The study included participants from different countries of Latin America including Panama, Costa Rica, El Salvador, Chile, and the Dominican Republic. The author included F1, F2, and duration as the main measurements to be taken. As in the current study, the results for male and female participants were reported separately. The results of the study indicate that unintelligibility takes place when male Spanish speakers produce the English vowel sounds [ɪ] and [e]. The vowels [ɪ] and [i] are also problematic because they can be confused with each other. The English back vowels that may cause unintelligibility for male Spanish speakers are [u] and [ʊ]. For female Spanish speakers, the study shows that the pair of vowel sounds [ɪ] and [i] are confused as are the sounds [ɔ] and [ʌ] because they are in the same position in the acoustic vowel space. The main conclusion of the study is that female Spanish speakers are more intelligible when speaking English than male Spanish speakers.

Salvadoran-accented English. Peña (2019) studied Salvadoran-accented English vowels in isolation. The results show intelligibility issues with the *goat* vowel [o] and the *cloth* vowel [ɔ], as the acoustic distance in F1 between those vowel sounds is only 9 Hz. This can lead to confusion in words like <goat> and <got>. The *kiss* vowel [ɪ] and the *face* vowel [e] may also be confused because the distance between their F1s is only 12 Hz.

Thai Speakers. In a study conducted by Koffi and Ruanglertslip (2013) on a Thai speaker, the results show intelligibility issues with the *goat* vowel [o] and the *cloth* vowel [ɔ], as the acoustic distance in F1 between those vowel sounds is 0 Hz. This can lead to confusion in words like <goat> and <got>. The *face* vowel [e] and the *dress* vowel [ɛ] may also be confused because the distance between their F1s is 33 Hz. The sounds [i] and [ɪ] may also present intelligibility issues as their F1s are 40Hz apart.

Chinese Speakers. Zhang (2014) studied Chinese-accented English vowels. The results of the study include relevant information on the vowels that may cause unintelligibility. The *cloth* vowel [ɔ] and the *cut* vowel[ʌ] have 0 Hz of acoustic difference. These vowels are sure to cause intelligibility issues in words like <cut> and <caught>. Also, the *geese* vowel [i] produced by the Chinese participant and the *kiss* vowel [ɪ] produced by GAE speakers can cause intelligibility issues. Finally, the *dress* vowel sound [ɛ] produced by the Chinese participant and the *trap* vowel sound [æ] in GAE would cause confusion when the Chinese participant says the words <beg> and <bag>.

Portuguese Speakers. Koffi and Ribeiro (2016) studied the English vowels produced by a Portuguese speaker. The results of the study indicate that the sounds [ʌ] (620 Hz) and [ʊ] (603 Hz) mask each other because their F1s are 17 Hz apart, which means that when the participant says the words

<book> and <buck> they would be perceived as the same word and it would cause unintelligibility issues; however, intelligibility is not seriously compromised because the relative functional load (RFL) between these two sounds is only 9%. The sounds [æ] (829 Hz) and [ɑ] (826 Hz) also mask each other because their F1s are within 3 Hz; this can be the cause of serious unintelligibility since the relative functional load for these two sounds is 76% (p. 86).

Arabic Speakers Packer and Lorincz (2013) conducted a study on an Arabic speaker. The study shows that the *kiss* vowel [ɪ] and the *face* vowel [e] produced by the participant can cause intelligibility issues since the vowel [ɪ] has been lowered and [e] has been raised and fronted which has caused them to merge closer than in GAE. In addition, participant's pronunciation of the *goose* vowel [u] and the *goat* vowel [o] is also problematic since the sound [u] has been lowered and centralized, whereas the sound [o] has been raised. The two sounds occur closer to the sound [ʊ] produced in GAE; Thus. the proximity of these three vowel sounds may cause intelligibility issues.

Methodology

In this part of the chapter, the research questions, the participants, the procedures, and the data analysis techniques are included.

Research Questions

1. How do L2 Salvadoran-accented English vowels compare to those produced by speakers of General American English?
2. Are there vowels produced by Salvadoran-accented English that cause intelligibility issues in running speech?
3. What are the L2 Salvadoran-accented English vowels that may cause intelligibly issues when interacting with other English speakers?

4. Is there any difference in intelligibility between Salvadoran-accented vowels in isolation and Salvadoran-accented vowels in running speech?

Equipment

Acer Aspire E15 laptop with an Intel core i5 processor, 8GB of RAM memory, and a 500GB SSD.

The speech accent archive (2020) uniformly presents a large set of speech samples from a variety of language backgrounds.

Praat 6. 1. 42 (Boersma & Weenick, 2020) is a free computer software program that was used to measure the acoustic correlates of F0, F1, F2, F3, duration, and intensity of the vowels.

Participants

The focus of the research is on Salvadoran English speakers; all the samples are of Spanish speakers from El Salvador. Due to the current COVID-19 pandemic, collecting data from participants currently in El Salvador was not possible because there are travel restrictions now, and the lead researcher cannot travel to El Salvador to record the samples. However, samples of Salvadoran speakers are available at the Speech Accent Archive (2020). It is a reliable website containing recordings of speakers from different countries and languages and has been used in numerous studies. On the website, there are 25 samples of Salvadoran English speakers from different regions of El Salvador. There are 10 male samples and 15 female samples. The ages of the participants range from 22 to 39 years old. For this research, all the samples were analyzed.

Procedures

The methodology of this study replicates that used by Peterson and Barney (1952). The vowel sound measurements were extracted from the following elicitation paragraph:

Please call Stella. Ask her1 to bring these things with her2 from the1 store: Six spoons of fresh snow peas, five thick slabs of blue cheese, and maybe a snack for her3 brother Bob. We also need a small plastic snake and a big toy frog for the2 kids. She can scoop these things into three red bags, and we will go meet her Wednesday at the3 train station.

The preceding text includes all the General American English (GAE) vowels except for the *foot* vowel [ʊ], and this paragraph has been used for numerous other studies. The correlates that were analyzed are F0, F1, F2, F3, and F4. The vowels to be measured are the following ones:

1. Please, peas, meet = Vowel sound /i/ = *geese*
2. With, thick, big = Vowel sound /ɪ/ = *kiss*
3. Maybe, snake, station = Vowel sound /e/ = *face*
4. Stella, fresh, red = Vowel sound /ɛ/ = *dress*
5. Ask, slab, snack= Vowel sound /æ/ = *trap*
6. Brother, Bob, frog = Vowel sound /ɑ/ = *lot*
7. Call, From, store = Vowel sound /ɔ/ = *thought*
8. Also, snow, go = Vowel sound /o/ = *goat*
9. Spoons, blue, scoop = Vowel sound /u/ = *goose*
10. The1, the2, the3 = Vowel sound /ə/ = *comma*
11. Her1, her2, her3 = vowel sound /ɚ/ = *letter*

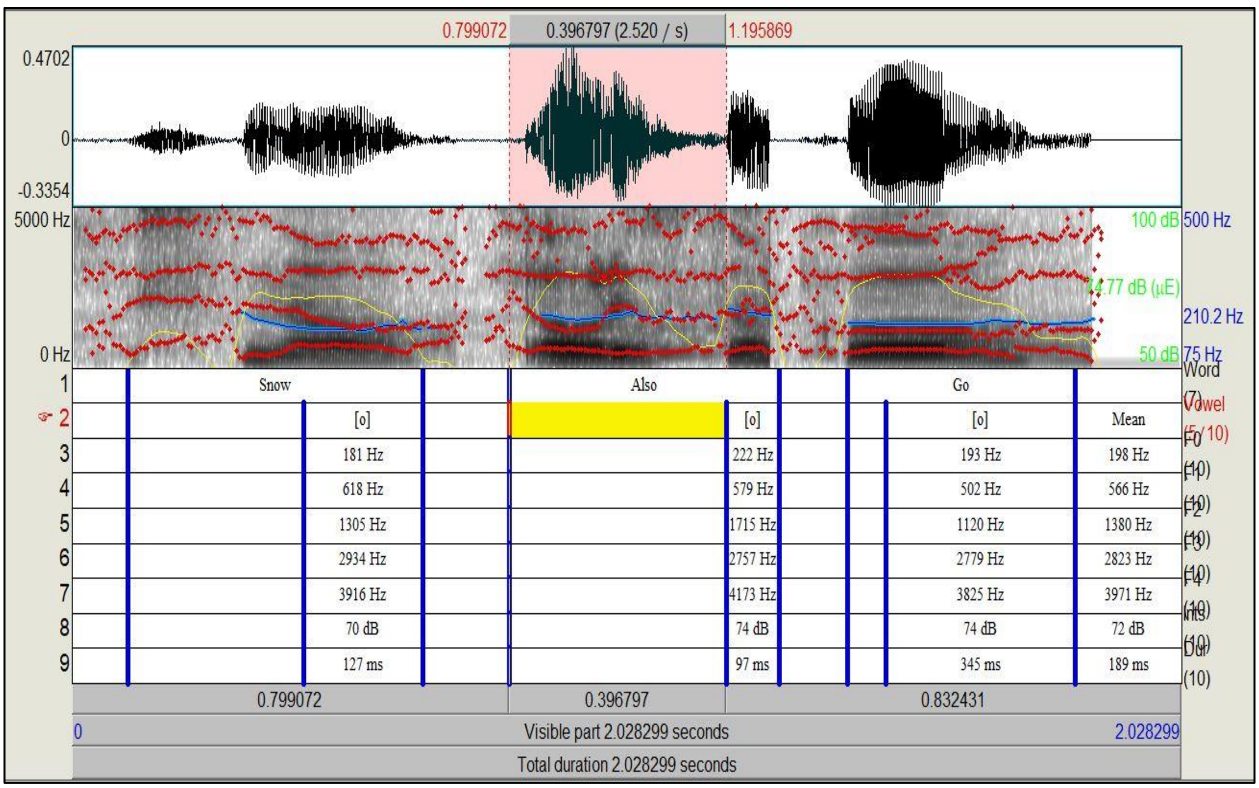
The recordings for this study were obtained from The Speech Accent Archive (2020) at https://accent.gmu.edu. The mp3 file of each participant was downloaded and then converted to WAV for its analysis using Praat.

Analysis

Praat was used in this study to analyze the WAV files from the Speech Accent Archive. The WAV files found there comprise all the recording of the full paragraph. The first step was to edit the file with Praat to include only the words that contain the same vowel sound. Then, spectrographs were created using the software, and the spectrographs include measurements for the correlates F0, F1, F2, F3, duration, and intensity of each word in the sets. Figure 1.3 is an example from the female participant 1 in this study.

Figure 1.2

Spectrograph Sample



Chapter II: Internal Masking Analysis of Female and Male Participants

Introduction

This chapter includes the acoustic phonetic characteristics of male and female Salvadoran speakers of English with a complete intelligibility analysis. The chapter will focus on the internal masking analysis to compare how vowels mask other vowels produced by the male and female participants. Male and female vowel data for F1 and F2 are given along with a vowel space depiction and an intelligibility assessment as it relates to internal masking.

The chapter is divided into two main sections: analysis of the female participants and analysis of male participants. Each of the sections lists three sub-topics: vowel height (F1), tongue movement (F2), and a comprehensive vowel space description with an internal masking and intelligibility analysis. At the end of the chapter, an analysis of the vowels and a summary of both male and female vowels is included.

According to Koffi (2021), "An internal masking analysis has to do with the degree of separation between two pairs of adjacent front, back, central, or low vowels produced by the same speaker or same group of speakers."

Female Participants

This part of the chapter will be used to analyze the vowels of the female participants. Vowel height, tongue movement, and internal masking analysis are parts that are included here.

Vowel Height Analysis According to F1 Data

Vowel height is determined by F1; that data will be used to analyze the height of each of the vowels produced by Salvadorans (female and male). Ladefoged and Johnson (2015, p. 221) state that the frequency of the first formant (F1) shows the relative height accurately. Table 2.1 below presents the vowel height measurements for the 15 female participants.

Table 2.1

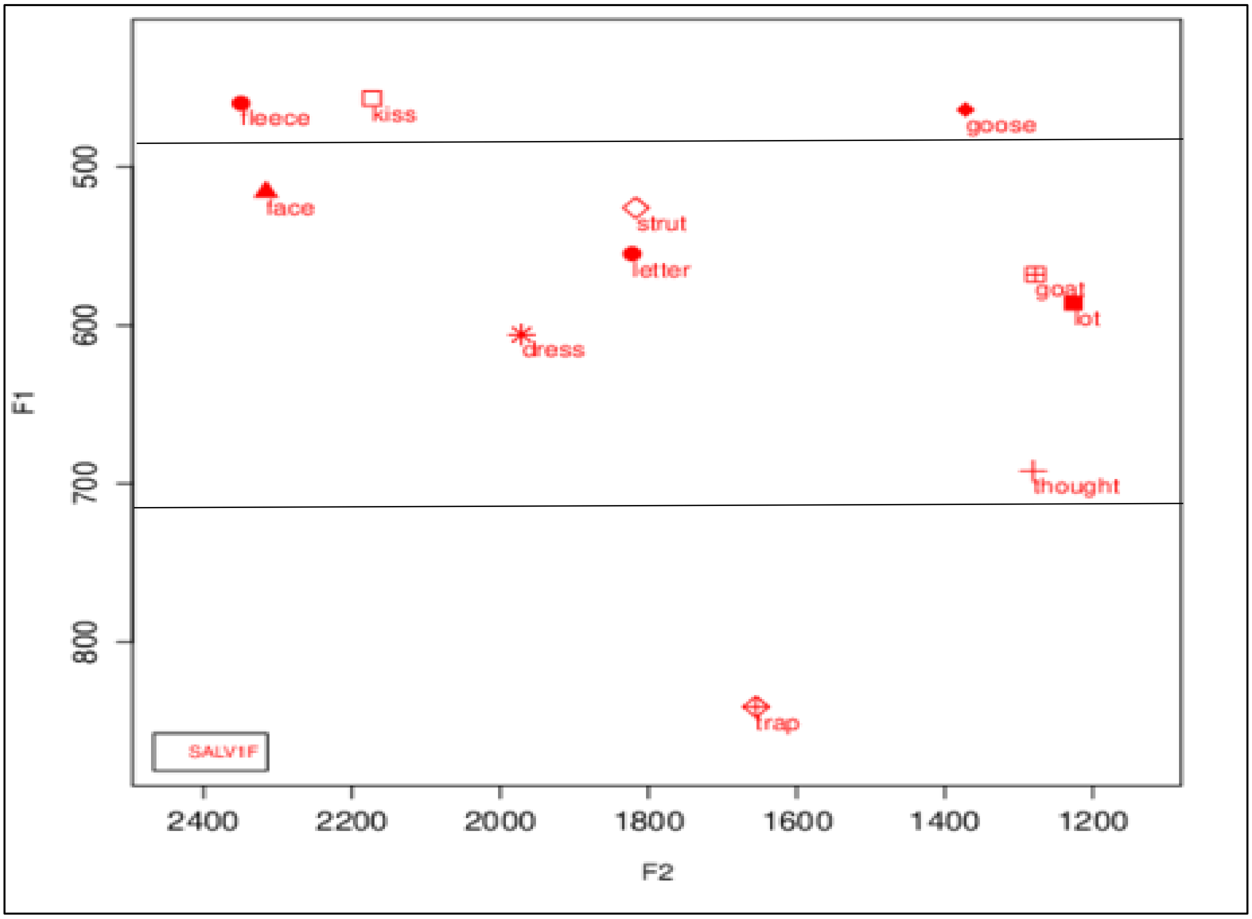
SALV Female F1 Measurements (measured in Hz)

Vowel sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F1 correlate	**[i]**	**[I]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	407	419	494	486	712	565	584	566	452	608	549
SALV2F	435	508	549	606	997	582	670	688	494	463	570
SALV3F	518	498	653	625	789	650	657	581	569	447	581
SALV4F	464	448	521	651	857	608	709	599	459	727	586
SALV5F	489	448	506	621	869	597	783	618	480	547	529
SALV6F	458	464	484	605	881	547	764	524	547	441	571
SALV7F	458	459	664	670	823	599	648	641	495	532	629
SALV8F	392	385	458	490	849	495	587	490	402	418	526
SALV9F	475	532	523	603	845	661	814	598	563	723	611
SALV10F	430	490	556	624	889	741	628	512	452	558	504
SALV11F	378	367	473	582	807	539	699	522	390	486	504
SALV12F	388	533	462	665	858	581	654	526	412	555	523
SALV13F	836	446	451	638	709	534	692	487	397	396	515
SALV14F	408	486	426	656	774	564	740	619	465	483	590
SALV15F	358	372	522	574	949	530	747	551	377	503	536
Mean	**460**	**457**	**516**	**606**	**841**	**586**	**692**	**568**	**464**	**526**	**555**
St. Deviation	**113**	**53**	**68**	**56**	**77**	**62**	**69**	**59**	**62**	**99**	**39**
MN	**404**	**485**	**462**	**636**	**821**	**780**	**577**	**526**	**427**	**674**	**542**

Backstrom (2018, pp. 28-29) defines the boundaries to analyze the vowel space for male and female vowels. On the F1 frequency for female participants, vowels are qualified as high vowels for heights under 480 Hz. They are classified as mid vowels for an F1 between 480 and 720 Hz. All F1 measurements above 720Hz are considered as low vowels. The full characteristics of the female vowel height are presented below based on these thresholds. Female participants produce most of their vowels as mid vowels (63.6%). They only have one low vowel (9.1%) and three high vowels (27.3%), as shown in the vowel space in Figure 2.1 below.

Figure 2.1

Female SALV Vowel Height Levels



The *kiss* vowel [ɪ] (457 Hz) is the highest vowel followed by the *fleece* vowel [i] (460 Hz). The *goose* vowel [u] (464 Hz) is the lowest of the high vowels with only 16 Hz of distance from the mid vowel boundary of 480 Hz. The standard deviation is 62 Hz with 5 (33.3%) participants producing it as a mid-vowel and the rest of the participants (66.6%) producing it as a high vowel.

The mid vowels are the *face* vowel [e] (516 Hz), the *dress vowel* [ɛ] (606 Hz), the *goat* vowel [o] (568 Hz), the *lot* vowel [ɑ] (586 Hz), the *comma* [ə] vowel (526 Hz), the *letter* vowel [ɚ] (555 Hz), and the *thought* vowel [ɔ] (692 Hz). Here, the *letter* [ɚ] vowel is the most stable sound with the lowest standard deviation of all female vowels (39 Hz).

The female participants only have one low vowel: the *trap* vowel [æ] (841 Hz). The *trap* vowel [æ] is produced as a mid-vowel by only one of the participants (6.6%). The rest of the participants produce it as a low vowel (93.3%).

Horizontal Tongue Movement Analysis According to F2 Data

The cornerstone of Table 2.2 is tongue advancement and retraction (F2). The Just Noticeable Difference threshold for F2 is 200 Hz. The data below shows that most of the vowel sounds (54.5%) are consistent between themselves for tongue movements. The standard deviations of five vowels (45.45%) go beyond the 200 Hz limit.

Table 2.2

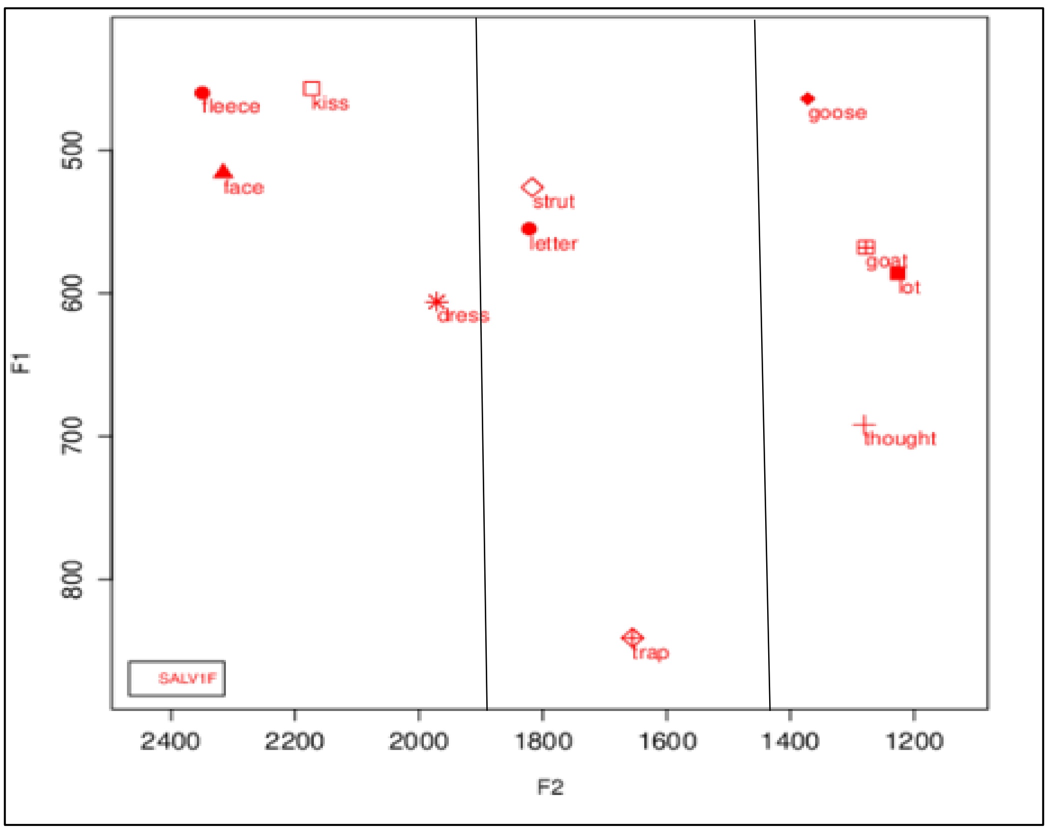
Female SALV F2 Measurements (measured in Hz)

Vowel sound	fleece	kiss	face	dress	trap	lot	thought	goat	goose	comma	letter
F2 correlate	**[i]**	**[I]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	2399	2139	2118	2243	1777	1305	1313	1380	1178	1793	1481
SALV2F	2365	2323	2496	1893	1802	1294	1472	1487	1414	1922	1720
SALV3F	2289	2322	2081	1883	1490	1250	1183	1264	1401	509	1654
SALV4F	2236	2378	2524	1815	1628	1367	1265	1137	1276	1645	1666
SALV5F	2612	2105	2361	1946	1538	1053	1311	1171	1388	1954	1313
SALV6F	2406	1383	2555	2067	1768	1188	1422	1367	1556	1950	1699
SALV7F	2295	2392	2205	2084	1661	1353	1217	1346	1152	2031	1868
SALV8F	1991	1991	1952	1773	1558	1137	1175	1265	1327	1824	1630
SALV9F	2374	2287	2355	2111	1861	1231	1391	1221	1432	1750	3585
SALV10F	2637	2567	2430	2327	1696	1448	1153	983	1391	2349	2373
SALV11F	2597	2485	2515	2060	1687	1059	1230	1204	911	1987	1749
SALV12F	2474	2310	2416	1795	1775	1186	1298	1373	1639	2065	1712
SALV13F	1821	1987	2095	1852	1632	1288	1309	1262	1227	1801	1382
SALV14F	2350	1597	2306	1759	1316	1138	1205	1428	1624	1898	1741
SALV15F	2409	2335	2327	1951	1631	1108	1272	1275	1665	1782	1759
Mean	**2350**	**2173**	**2316**	**1971**	**1655**	**1227**	**1281**	**1278**	**1372**	**1817**	**1822**
St. Deviation	**218**	**325**	**187**	**173**	**140**	**117**	**93**	**127**	**206**	**398**	**543**
MN	**2434**	**1948**	**2374**	**1661**	**1731**	**1382**	**1325**	**1269**	**1557**	**1557**	**1615**

Backstrom (2018, pp. 28-29) states that for the female F2 frequency, vowels are classified as front vowels in the region above 1920 Hz. They are qualified as central vowels if their F2 ranges between 1440 Hz and 1919 Hz. Any vowels with a value under 1440Hz are considered back vowels. Female *SALV* participants pronounce vowels in the three different regions based on tongue movement. According to these thresholds, these participants use equally the front and back regions for vowels with four each. Only three vowels are central to their speech, as seen below (Figure 2.2).

Figure 2.2

Female SSE Vowel Tongue Regions



The *fleece* vowel [i] (2350 Hz), the *face* vowel [e] (2316 Hz), the *kiss* vowel [ɪ] (2173 Hz) and the *dress* vowel [ɛ] (1971 Hz) are fronted vowels. The most fronted vowel is the *fleece* vowel [i], with a standard deviation of 218 Hz. Only one participant (SALV13F) produces that vowel at 1821 Hz, making it a central vowel as produced by that participant. The *trap* vowel [æ] (1655 Hz), the *letter* vowel [ɚ] (1822 Hz), and the *comma* vowel [ə] (1817 Hz) are central vowels. The *letter* vowel [ɚ] is the most unstable with the highest standard deviation (543 Hz) of all vowels. There are two participants (13.3 %) producing the sound as a back vowel and two participants (13.3%) producing it as a fronted vowel. Also, the *comma* vowel [ə] is an unstable central vowel with seven participants (46.6%) producing it as a fronted vowel and one participant (6.6%) producing it as a back vowel. Participant SALV3F produces this vowel as a back vowel, at only 509 Hz.

The back vowels are the *goose* vowel [u] (1372 Hz), the *lot* vowel [ɑ] (1227 Hz), the *thought* vowel [ɔ] (1281 Hz), and the *goat* vowel [o] (1278 Hz). The most stable vowel produced is the *thought* sound [ɔ], with the lowest standard deviation for all regions at 93 Hz. The *goose* vowel [u] has the highest standard deviation (206 Hz) for back vowels.

Summary Observations. The acoustic vowel space for female participants points out the following distinctiveness. The *fleece* vowel [i], the *kiss* vowel [ɪ], and the *goose* vowel [u] are the high vowels in the speech of 15 participants. As mid-vowels, SALV females produce the *letter* vowel [ɚ], the *face* vowel [e], the *dress* vowel [ɛ], the *thought* vowel [ɔ], the *comma* vowel [ə], the *lot* vowel [ɑ], and the *goat* vowel [o]. The *trap* vowel [æ] is the only vowel produced as a low vowel.

Internal Masking and Intelligibility

Masking measurements of F1 and RFL (Relative Functional Load) are used to determine the seriousness of intelligibility. Koffi (2021, p. 75) established the thresholds used in this vowel analysis. For the focus of this study, vowels with complete masking will be highlighted. The complete masking threshold is an acoustic distance of < 20 Hz between two different phonemes. The vowels that Salvadoran female participants in the study have a hard time differentiating and which can cause intelligibility issues are summarized in Table 2.3 below. For the female Salvadoran participants, there is only one vowel that has complete masking.

Table 2.3

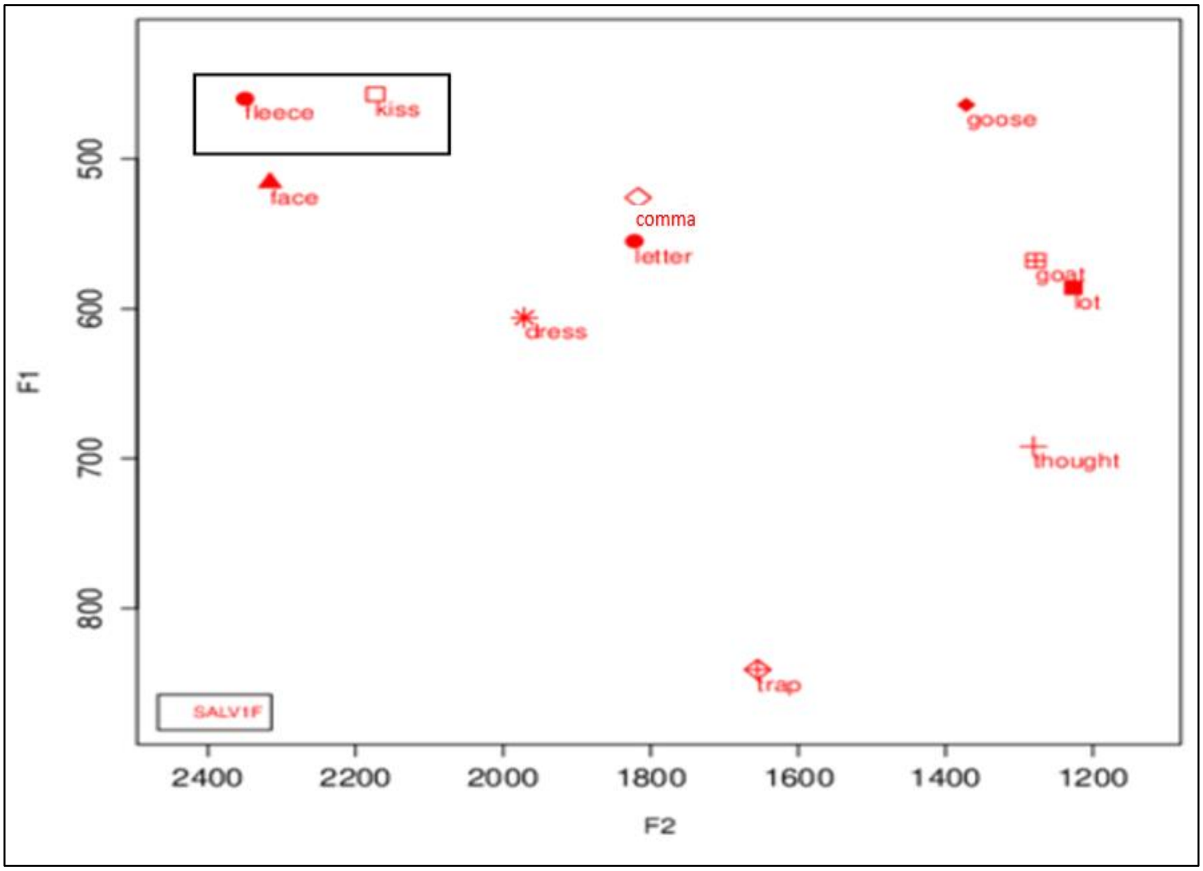
Internal Masking and Intelligibility of Female SSE Vowels (adapted from “Acoustic Distance and Intelligibility,” Koffi, 2021, pp. 48, 50, & 75)

Vowel Pairs	**F1 Distance**	**Internal Masking Levels**	**RFL**	**Intelligibility Rating**
[i] (460 Hz) vs. [ɪ] (457 Hz)	**3 Hz**	**Complete masking**	**95%**	**Poor intelligibility**
[ɪ] (457 Hz) **vs. [e]** (516 Hz)	59 Hz	Slight masking	80%	Poor intelligibility
[e] (516 Hz) vs. [ɛ] (606 Hz)	90 Hz	No masking	53%	Mediocre intelligibility
[ɛ] (606 Hz) vs. [æ] (841 Hz)	235 Hz	No masking	53%	Mediocre intelligibility
[u] (464 Hz) vs. [o] (568 Hz)	104 Hz	No masking	51%	Good intelligibility
[o] (568 Hz) vs. [ɔ] (692 Hz)	124 Hz	No masking	88%	Poor intelligibility
[ɔ] (692 Hz) vs. [ɑ] (586 Hz)	106 Hz	No masking	26%	Fair intelligibility
[æ] (841 Hz) vs. [ɚ] (555 Hz)	286 Hz	No masking	68%	Mediocre intelligibility
[ɚ] (555 Hz) vs. [ɑ] (586 Hz)	31 Hz	Moderate masking	65%	Mediocre intelligibility
[æ] (841 Hz) vs. [ɑ] (586 Hz)	255 Hz	No masking	76%	Poor intelligibility

The only complete internal masking with is a fronted vowel. The acoustic distance between the *fleece* vowel [i] (460 Hz) and the *kiss* vowel [ɪ] (457 Hz) is only 3 Hz, which indicates complete masking. With an RFL at 95%, the intelligibility is poor. For example, when a female Salvadoran speaker of English says <cheap> and <chip>, no difference would be audible. Gilner and Morales (2010) used the transcription and analysis of the 10,000 most frequent words in spoken English in one of their studies. The frequency of occurrence of the *fleece* vowel (13.83%) and the *kiss* vowel (14.69%) can also impact intelligibility, as both vowels account for the 28.52% of all vowel occurrences. This is the only intelligibility issue shown in Figure 2.3 below.

Figure 2.3

Internal Masking for Female SALV Vowels



Overall, the intelligibility of female Salvadoran vowels in terms of internal masking is very robust. SALV females can distinguish most of their vowels with no intelligibility issues. Eight of their 11 (72%) vowels are completely distinguishable from each other with more than 60 Hz of distance between them. Only the *fleece* vowel [i] leads to poor intelligibility because of a complete masking with the *kiss* vowel [ɪ] and an associated RFL of 95%. The *letter* vowel [ɚ] (555 Hz) and the *lot* vowel [ɑ] (586 Hz) lead to mediocre intelligibility with an RFL of 65%.

Male Participants

This part of the chapter will be used to analyze the vowels of the male participants. Vowel height, tongue movement, and internal masking analysis are parts that are included here.

Vowel Height Analysis According to F1 Data

As stated before, vowel height is determined by F1; that data will be used to analyze the height of each of the vowels produced by Salvadorans. Table 2.4 below presents the vowel height measurements for the 10 male participants (F1).

Table 2.4

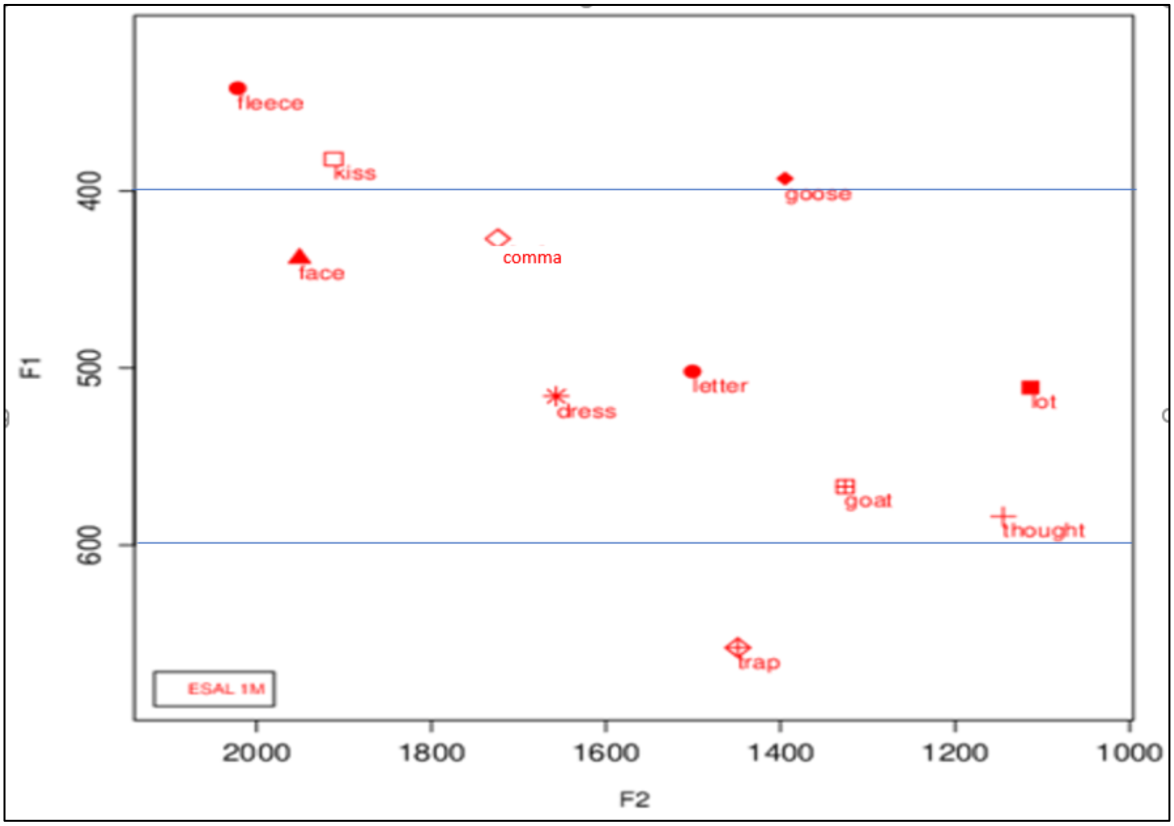
SALV Male F1 Measurements

Vowel sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F1 correlate	**[i]**	**[I]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	340	348	399	478	652	423	550	511	360	370	429
SALV2M	333	327	399	486	621	513	515	405	383	382	421
SALV3M	304	443	423	626	645	606	697	539	347	425	691
SALV4M	386	382	503	528	725	542	553	607	473	408	505
SALV5M	297	368	408	486	670	529	608	512	417	503	461
SALV6M	327	359	411	487	689	501	472	530	354	450	484
SALV7M	343	446	505	545	624	501	620	528	386	458	471
SALV8M	410	435	497	531	652	542	570	855	481	418	497
SALV9M	348	324	409	478	582	467	595	526	360	433	455
SALV10M	327	388	422	514	718	488	660	660	372	425	607
Mean	**342**	**382**	**438**	**516**	**658**	**511**	**584**	**567**	**393**	**427**	**502**
St. Deviation	**34**	**46**	**45**	**46**	**44**	**49**	**67**	**121**	**48**	**38**	**84**
MN	**318**	**408**	**404**	**477**	**641**	**672**	**580**	**445**	**362**	**537**	**492**

Koffi (2021, p. 75) offers frequency ranges for male participants. On the F1 frequency for male participants, vowels are qualified as high vowels for heights under 400 Hz. They are classified as mid vowels for an F1 between 400 and 600 Hz. All F1 measurements above 600 Hz are considered as low vowels. The full characteristics of the male vowel height are presented below based on these thresholds. It is noteworthy that the same patterns are repeated for female and male participants. SALV males produce most of their vowels as mid vowels (63.6%). They only have one low vowel (9.1%) and three high vowels (27.3%), as shown in the vowel space map, Figure 2.4 below.

Figure 2.4

Male SALV Vowel Height Levels



The *fleece* vowel [i] (342 Hz) is the highest vowel, followed by the *kiss* vowel [ɪ] (382 Hz). The *goose* vowel [u] (393 Hz) is the lowest of the high vowels, with only 7 Hz of distance from the mid vowel boundary of 400 Hz. The standard deviation for that vowel is 48 Hz, with three participants (30%) producing it as a mid-vowel and the rest of the participants (70%) producing it as a high vowel. The most stable vowel in the male set of vowels is the *fleece* vowel [i] with a standard deviation of 34 Hz. Nine participants (90%) produce it as a high vowel; only one of them (10%) produces it as a mid-vowel.

The mid vowels are the *face* vowel [e] (438 Hz), the *dress vowel* [ɛ] (516 Hz), the *goat* vowel [o] (567 Hz), the *lot* vowel [ɑ] (511 Hz), the *comma* [ə] vowel (427 Hz), the *letter* vowel [ɚ] (502 Hz), and the *thought* vowel [ɔ] (584 Hz). Here, the *comma* [ə] vowel is the most stable sound with a standard deviation of 38 Hz.

The male participants only have one low vowel: the *trap* vowel [æ] (658 Hz). The *trap* vowel [æ] is produced as a mid-vowel by only one of the participants (10%). The rest of the participants produce it as a low vowel (90 %).

Horizontal Tongue Movement Analysis According to F2 Data

Table 2.5 deals with tongue advancement and retraction (F2). The Just Noticeable Difference threshold for F2 is 200 Hz. The data below shows that almost all the vowel sounds (90.9%) are consistent between themselves for tongue movements. The only exception to the rule is the *goose* vowel [u] (9.1%). With a standard deviation of 217 Hz, that vowel goes beyond the 200 Hz limit.

Table 2.5

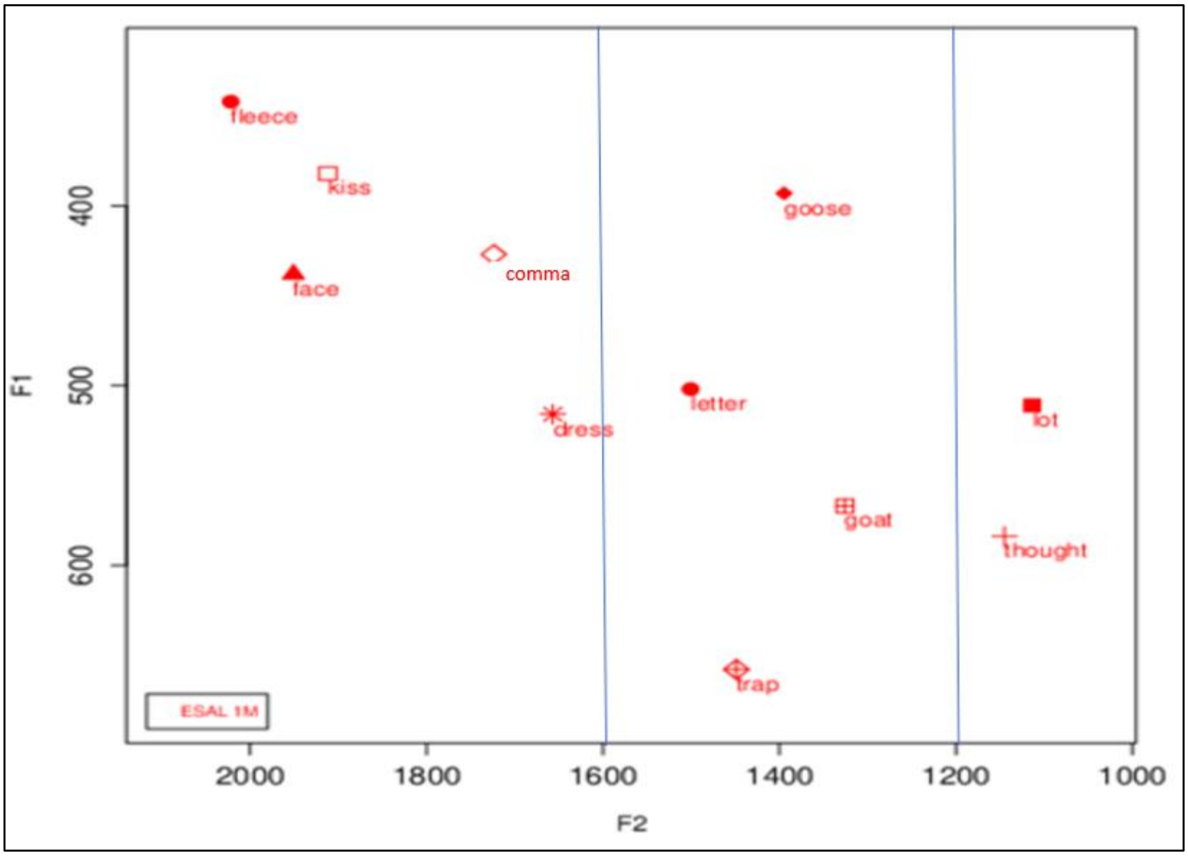
Male SALV F2 Measurements

Vowel sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**lette r**
F12correlate	**[i]**	**[I]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	2086	2016	2022	1772	1383	1018	1091	1350	1440	1815	1560
SALV2M	1698	1892	1934	1607	1422	1241	1104	1250	1181	1732	1559
SALV3M	2264	1817	2134	1719	1591	1095	1466	1527	1608	1703	1660
SALV4M	2001	1970	1986	1699	1390	1220	1064	1304	1397	1806	1256
SALV5M	1959	1822	1884	1691	1474	1064	1162	1231	1637	1722	1563
SALV6M	1880	1913	1594	1530	1279	1024	968	1215	955	1615	1285
SALV7M	1976	1781	1867	1646	1493	1092	1133	1147	1238	1768	1430
SALV8M	2133	2211	2062	1685	1411	1196	1070	1515	1591	1630	1570
SALV9M	2053	1904	1968	1602	1395	1095	1193	1138	1391	1688	1585
SALV10M	2167	1796	2055	1617	1651	1099	1201	1584	1512	1762	1541
Mean	**2022**	**1912**	**1951**	**1657**	**1449**	**1114**	**1145**	**1326**	**1395**	**1724**	**1501**
St. Deviation	**159**	**130**	**150**	**70**	**108**	**78**	**132**	**163**	**217**	**67**	**134**
MN	**2007**	**1659**	**2070**	**1484**	**1569**	**1174**	**1260**	**1097**	**1555**	**1266**	**1471**

For the male F2 frequency, vowels are considered as front vowels in the region above 1600 Hz. They are central vowels if their F2 ranges between 1200 Hz and 1599 Hz. Vowels with a value under 1200 Hz are classified as back vowels. Male *SALV* participants pronounce vowels in the three different regions based on tongue movement. According to the data, these participants do not use the front, center, and back regions uniformly. They pronounce five vowels in the front region, four vowels in the center region, and only two vowels in the back region. Figure 2.5 is a graphic representation of the F2 values of the male participants.

Figure 2.5

Male SSE Vowel Tongue Regions



The *fleece* vowel [i] (2022 Hz), the *face* vowel [e] (1951 Hz), the *kiss* vowel [ɪ] (1912 Hz), the *comma* vowel [ə] (1724 Hz), and the *dress* vowel [ɛ] (1657 Hz) are fronted vowels. The most fronted vowel is the *fleece* vowel [i] with a standard deviation of 159 Hz. All the male participants produce that vowel as a fronted vowel. The *dress* vowel [ɛ] is an unstable vowel, with 1 participant (10%) producing it as a central vowel. Having a standard deviation of only 70 Hz, most of the *dress* vowel [ɛ] F2 values are close to the 1600 Hz boundary, which would make them centered vowels. The *trap* vowel [æ] (1449 Hz), the *letter* vowel [ɚ] (1501 Hz), the *goose* vowel [u] (1395 Hz), and the *goat* vowel [o] (1326 Hz) are central vowels. The *goose* vowel [u] is the most unstable, with the highest standard deviation (217 Hz) among all vowels. Two participants (20 %) produce the sound as a back vowel.

The back vowels are the *lot* vowel [ɑ] (1227 Hz) and the *thought* vowel [ɔ] (1281 Hz). Among all the vowel sounds, the most stable vowel produced by male participants is the *comma* vowel [ə], with a standard deviation of just 67 Hz.

Summary Observations. The acoustic vowel space for male participants points out the following characteristics. The *fleece* vowel [i], the *kiss* vowel [ɪ], the *dress* vowel [ɛ], the *face* vowel [e], and the *comma* vowel [ə] are produced as front vowels in the speech of 10 male participants. They produce the *letter* vowel [ɚ], the *goose* vowel [u], the *goat* vowel [o], and the *trap* vowel [æ] as centered vowels. Finally, the male participants produce the *thought* vowel [ɔ] and the *lot* vowel [ɑ] as low vowel.

Internal Masking and Intelligibility

As with the female participants, an intelligibility analysis including the measurements of F1 and RFL of the male participants is presented below. For the focus of this study, vowels with complete masking will be highlighted. The complete masking threshold is an acoustic distance of < 20 Hz between two different phonemes. The vowels that Salvadoran male participants in the study have a hard time differentiating and which can cause intelligibility issues are summarized in Table 2.6 below. For the male Salvadoran participants, as for the female participants, there is also only one vowel that has complete masking.

Table 2.6

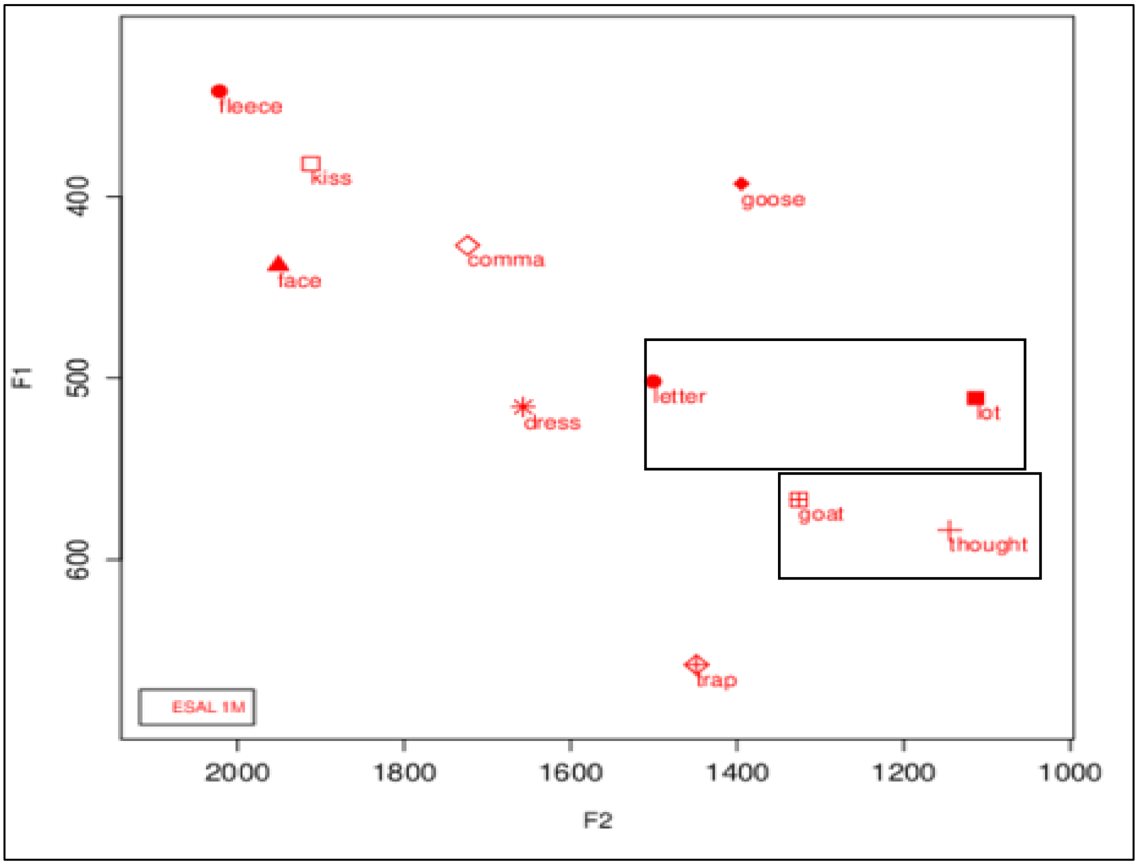
Internal Masking and Intelligibility of Male SSE Vowels

Vowel Pairs	F1 Distance	Internal Masking Levels	RFL	Intelligibility Rating
[i] (342 Hz) vs. [ɪ] (382 Hz)	40 Hz	Moderate masking	**95%**	**Poor intelligibility**
[ɪ] (382 Hz) vs. [e] (438 Hz)	56 Hz	Slight masking	80%	Poor intelligibility
[e] (438 Hz) vs. [ɛ] (516 Hz)	78 Hz	No masking	53%	Mediocre intelligibility
[ɛ] (516 Hz) vs. [æ] (658 Hz)	142 Hz	No masking	53%	Mediocre intelligibility
[u] (393 Hz) vs. [o] (567 Hz)	174 Hz	No masking	51%	Good intelligibility
[o] (567 Hz) vs. [ɔ] (584Hz)	**17 Hz**	**Complete masking**	**88%**	**Poor intelligibility**
[ɔ] (584 Hz) vs. [ɑ] (511 Hz)	73 Hz	No masking	26%	Fair intelligibility
[æ] (658 Hz) vs. [ɚ] (502 Hz)	156 Hz	No masking	68%	Mediocre intelligibility
[ɚ] (502 Hz) vs. [ɑ] (511 Hz)	**9 Hz**	**Complete masking**	**65%**	**Mediocre intelligibility**
[æ] (658 Hz) vs. [ɑ] (511 Hz)	147 Hz	No masking	76%	Poor intelligibility

There are two occurrences where intelligibility is a major issue. The first complete internal masking issue in this set of vowels is the one formed between the *goat* vowel [o] and the *thought* vowel [ɔ]. The acoustic distance between the *goat* vowel [o] (567 Hz) and the *thought* vowel [ɔ] (584 Hz) is only 17 Hz, which indicates complete masking. With an RFL at 88%, the intelligibility is poor. For example, when a male Salvadoran speaker of English says <so> and <saw>, no difference would be audible. The second complete internal masking issue in this set of vowels is the one formed between the *letter* vowel [ɚ] and the *lot* vowel [ɑ]. The acoustic distance between the *letter* vowel [ɚ] (502 Hz) and the *lot* vowel [ɑ] (511 Hz) is 9 Hz, which indicates complete masking. With an RFL at 65%, the intelligibility is mediocre. The two intelligibility issues are shown in Figure 2.6 below.

Figure 2.6

Internal Masking for Male SALV Vowels



Overall, the intelligibility of male Salvadoran vowels with regard to internal masking is good. Male Salvadorans can produce most of their vowels with no intelligibility issues when they speak. Seven of the eleven SALV male (63%) vowels are completely distinguishable from each other with more than 60 Hz of distance between them. The *letter* vowel [ɚ] leads to mediocre intelligibility because of a complete masking with the *lot* vowel [ɑ] and an associated RFL of 65%. Also, the *goat* vowel [o] and the *thought* vowel [ɔ] lead to poor intelligibility because of a complete masking and the associated RFL of 88%.

Discussion

Among the female participants, there are some cases that need to be highlighted. SALV1F's *face* vowel [e] (494 Hz) and *dress* vowel [ɛ] (486 Hz) have an acoustic difference of 8 Hz. This indicates that the participant produces both vowels in a similar way. With an RFL of 53%, the intelligibility is mediocre. The same participant produces the *thought* [ɔ] (584 Hz) vowel and the *goat* [o] (566 Hz) vowel similarly as well. With an RFL of 88%, the intelligibility is poor for that specific participant. SALV3F also has some internal masking issues. The *goat* vowel [o] (581 Hz) and the *goose* vowel [u] (569 Hz) have an acoustic difference of only 12 Hz. With an RFL of 51%, the intelligibility is good. SALV7F's *face* vowel [e] (664 Hz) *and dress* vowel [ɛ] (670 Hz) have an acoustic difference of 6 Hz. The intelligibility for those vowels is mediocre with an RFL of 53%. The same intelligibility issue is noticeable in SALV8F where the *face* vowel [e] (458 Hz) *and dress* vowel [ɛ] (490 Hz) have an acoustic difference of 32 Hz. There is moderate masking, and with the RFL of 53%, the intelligibility is mediocre. Finally, SALV9F's *goat* [o] (598 Hz) and *goose* [u] (563 Hz) vowels have intelligibility issues, with 35 Hz of acoustic difference. There is moderate masking, but there is good intelligibility with the RFL at 51%. Specific individuals among the male participants also have masking issues. SALV1M's *fleece* [i] (340 Hz) and *kiss* [I] (348 Hz) vowels have intelligibility issues, with 8 Hz of acoustic difference. There is moderate masking, and there is poor intelligibility with the RFL at 95%. Similarly, SALV2M, SALV4M, SALV6M, and SALV9M have intelligibility issues with the *fleece* vowel [i] (333 H, 386 Hz, 327 Hz, and 348 Hz respectively) and the *kiss* vowel [ɪ] (327 Hz, 382 Hz, 359 Hz, and 324 Hz respectively). The acoustic differences are 6 Hz, 4 Hz, 32 Hz, and 24 Hz, respectively. With the RFL at 95%, the intelligibility is poor. The *face* vowel [e] (503 HZ and 505 Hz) vowel and the *dress* vowel [ɛ]

(528 Hz and 545 Hz) is an issue for SALV4M and SALV7M. For SALV4M, the acoustic difference is 25 Hz and for SALV7M, 40 Hz. There is moderate masking for both participants, and with the RFL at 53%, the intelligibility is poor. Finally, the *thought* vowel [ɔ] (550 Hz and 660 HZ) and the *goat* vowel [o] (511 Hz and 660 Hz) is an issue for SALV1M and SALV10M. For SALV1M, there is an acoustic difference of 39 Hz, which leads to moderate masking. For SALV10M, the difference is 0 Hz. That means that the participant produces both vowel sounds in the same way. With the RFL at 88%, the intelligibility is poor.

Summary

Although both male and female participants in this study speak Spanish as a native language and come from the same country, they mask different vowels. Female participants pronounce the *fleece* vowel [i] (460 Hz) and the *kiss* vowel [ɪ] (457 Hz) in almost the same way with only 3 Hz of acoustic difference, creating a complete masking issue. On the other hand, male participants mask two pairs of vowels. The first pair is formed by the *goat* vowel [o] (567 Hz) and the *thought* vowel [ɔ] (584Hz), with an acoustic difference of 17 Hz. The second set of vowels that male participants mask is the pair formed by the *letter* vowel [ɚ] (502 Hz) and the *lot* vowel [ɑ] (511 Hz), with an acoustic difference of 9 Hz. In both cases, the masking is absolute.

Chapter III: External Masking Analysis

Introduction

In this chapter, female and male Salvadoran vowels are compared with the vowels produced by English speakers (female and male respectively) from Minnesota, with a focus on external masking. The chapter is divided into two main sections: analysis of the female participants and analysis of male participants. Each section lists two sub-topics: a vowel comparison and an external masking and intelligibility analysis. At the end of the chapter, an analysis of the vowels and a summary of both male and female vowels is included.

Female Participants

This part of the chapter will be used to make a vowel comparison between the vowels of the SALV female participants and the female MN speakers. A vowel comparison and an external masking and intelligibility analysis are presented.

Vowel Comparison

The comparison between the vowels produced by female speakers of Salvadoran-accented English and native speakers shows clearly that the *lot* vowel [ɑ], the *goose* vowel [u], and the *comma* vowel [ə] differ the most, as shown in Table 3.1.

Table 3.1

F1 and F2 Data for Female SALV and MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
Vowel	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
								F1			
Female SALV	460	457	516	606	841	586	692	568	464	526	555
Female MN	404	485	462	636	821	780	577	526	427	674	542
F1 difference	**56**	**28**	**54**	**30**	**20**	**194**	**115**	**42**	**167**	**148**	**13**
								F2			
Female SALV	2350	2173	2316	1971	1655	1227	1281	1278	1372	1817	1822
Female MN	2434	1948	2374	1661	1731	1382	1325	1269	1557	1557	1615
F2 difference	**84**	**225**	**58**	**310**	**76**	**155**	**44**	**9**	**185**	**260**	**207**

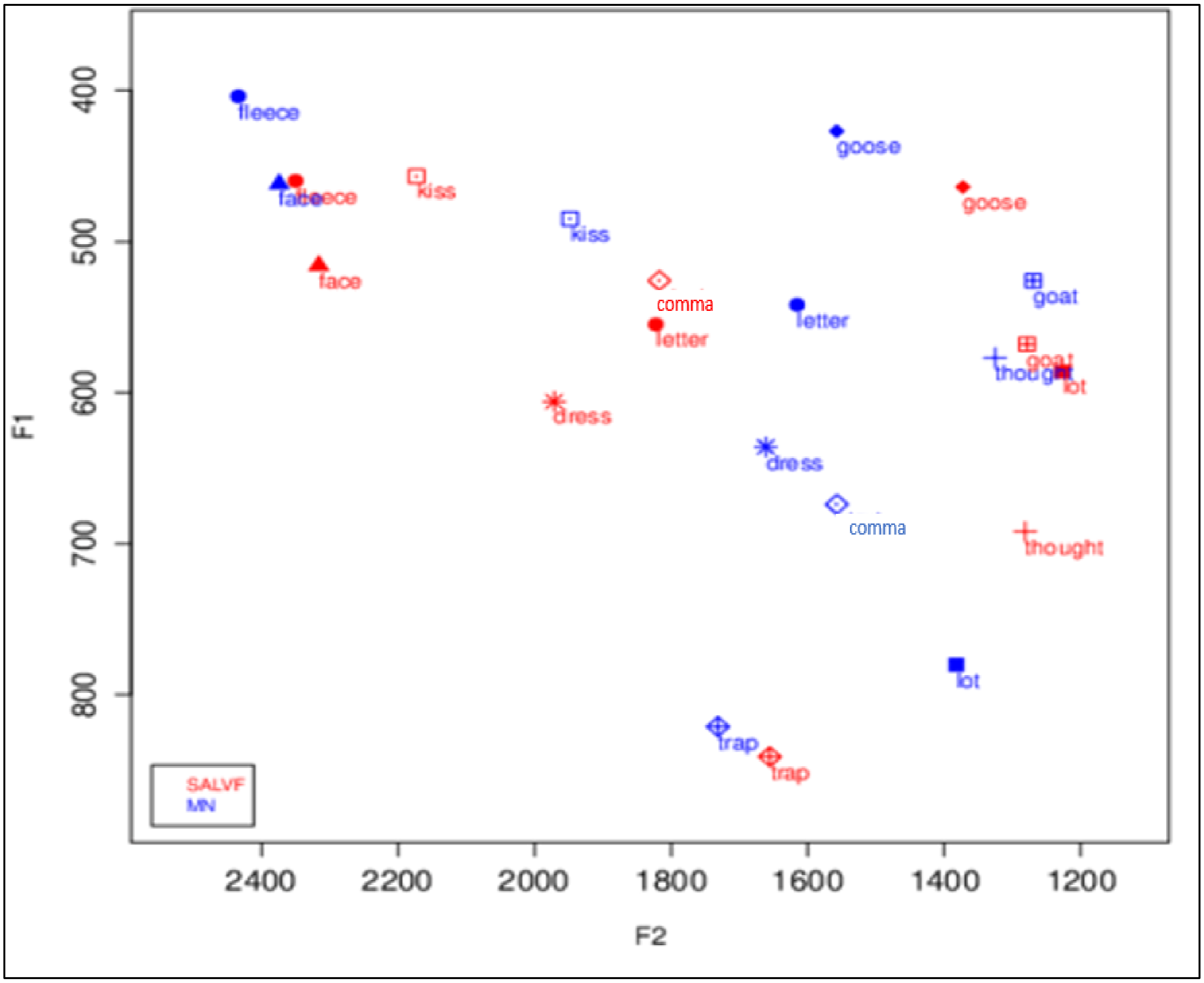
For female SALV speakers and MN speakers, the most noticeable differences in F1 are the *lot* vowel [ɑ] with an acoustic difference of 194 Hz, the *goose* vowel [u] with an acoustic difference of 167 Hz, and the *comma* vowel [ə] with an acoustic difference of 148 Hz. For F2, the most visible differences are the *dress* vowel [ɛ], the comma vowel [ə], and the *kiss* vowel [ɪ] with acoustic differences of 310 Hz, 260 Hz, and 225 Hz, respectively. The vowels listed above are those that female SALV speakers and female MN speakers produce most differently.

There are also occurrences where female SALV speakers and MN speakers produce vowels similarly. For F1, these vowels are the *letter* vowel [ɚ] and the *trap* vowel [æ], where the acoustic differences are 13 Hz and 20 Hz, respectively. For F2, the *goat* vowel, the *thought* vowel, and the *face* vowel are the ones that are closest to each other, with acoustic differences of 9 Hz, 44 Hz, and 58 Hz, respectively. The vowels listed above are the ones that female SALV speakers and female MN speakers produce most similarly.

By analyzing the information in the tables above, some similarities can be highlighted. Both female SALV speakers and MN speakers produce the *fleece* vowel [i] (SALV: 460 Hz vs MN: 404 Hz) as a high fronted phoneme. However, this high vowel produced by female MN speakers is higher by 64 Hz. This makes it the highest vowel produced by MN females. The *trap* vowel [æ] (SALV: 841 Hz vs MN: 821 Hz) is the lowest sound produced by both SALV and MN female speakers. The two are very close to each other with an acoustic difference of just 20 Hz. The *trap* vowel [æ] produced by female SALV speakers is the lowest vowel among all female speakers analyzed. The *letter* vowel [ɚ] produced by female SALV (555 Hz) and MN (542 Hz) speakers is also similar, with an acoustic difference of 13 Hz. Moreover, the *kiss* vowel [ɪ] and the *dress* vowel [ɛ] produced by female SALV speakers are also close to those produced by the MN counterparts with 28 Hz and 30 Hz of acoustic difference, respectively. To give a clearer comparison of all remaining vowels, the acoustic vowel space is provided in Figure 3.1.

Figure 3.1

Comparative Vowel Space for Female SALV and MN Vowels



More similarities between female Salvadoran English and female MN vowels are found in all three regions (front, central & back). The *fleece* vowel [i] and the *kiss* vowel [ɪ] are fronted high vowels in both female Salvadoran vowels and female MN vowels. The *comma* vowel [ə] and the *letter* vowel [ɚ] are both central-mid vowels. The *trap* vowel [æ] is the only central-low vowel for female SALV and MN speakers. Also, the *goat* [o] and *thought* [ɔ] vowels are similarly backed-mid vowels.

Some differences can be highlighted. The *lot* [ɑ] vowel is a backed-mid vowel in female MN English, but it is a backed-low vowel in female Salvadoran English. Also, the *dress* [ɛ] vowel is a central-mid vowel in female MN English; however, it is a fronted-mid vowel in female Salvadoran English. The *face* vowel [e] in female MN English is a fronted-high vowel, but it is lowered to a fronted-mid position in female Salvadoran English. The last noticeable difference is in the *goose* [u] vowel, as it is a central-high vowel in female MN English but a backed-high vowel in female Salvadoran English.

External Masking and Intelligibility

External masking calculates the acoustic distance between vowels produced by female Salvadoran speakers and those produced by female MN speakers. When the acoustic distance between two different phonemes is less than 20 Hz, they are considered to have complete external masking. Table 3.2 below presents the external masking measurements of the female SALV participants compared to the female MN participants. In this table, the first vowel in each row is produced by Salvadoran speakers, while in the second is by Minnesota speakers.

Table 3.2

External Masking and Intelligibility of Female SALV and Female MN Vowels

Vowel Pairs	F1 Distance	External Masking Levels	RFL	Intelligibility Rating
SALV vs. MN				
[i] (460 Hz) vs. [ɪ] (485 Hz)	25 Hz	Moderate masking	95%	Poor intelligibility
[ɪ] (457 Hz) vs. [e] (462 Hz)	**5 Hz**	**Complete masking**	**80%**	**Poor intelligibility**
[e] (516 Hz) vs. [ɛ] (636 Hz)	120 Hz	No masking	53%	Mediocre intelligibility
[ɛ] (606 Hz) vs. [æ] (821 Hz)	215 Hz	No masking	53%	Mediocre intelligibility
[u] (464 Hz) vs. [o] (526 Hz)	62 Hz	No masking	51%	Good intelligibility
[o] (568 Hz) vs. [ɔ] (577 Hz)	**9 Hz**	**Complete masking**	**88%**	**Poor intelligibility**
[ɔ] (692 Hz) vs. [ɑ] (780 Hz)	88 Hz	No masking	26%	Fair intelligibility
[æ] (841 Hz) vs. [ɚ] (542 Hz)	299 Hz	No masking	68%	Mediocre intelligibility
[ɚ] (555 Hz) vs. [ɑ] (780 Hz)	225 Hz	No masking	65%	Mediocre intelligibility
[æ] (841 Hz) vs. [ɑ] (780 Hz)	61 Hz	No masking	76%	Poor intelligibility

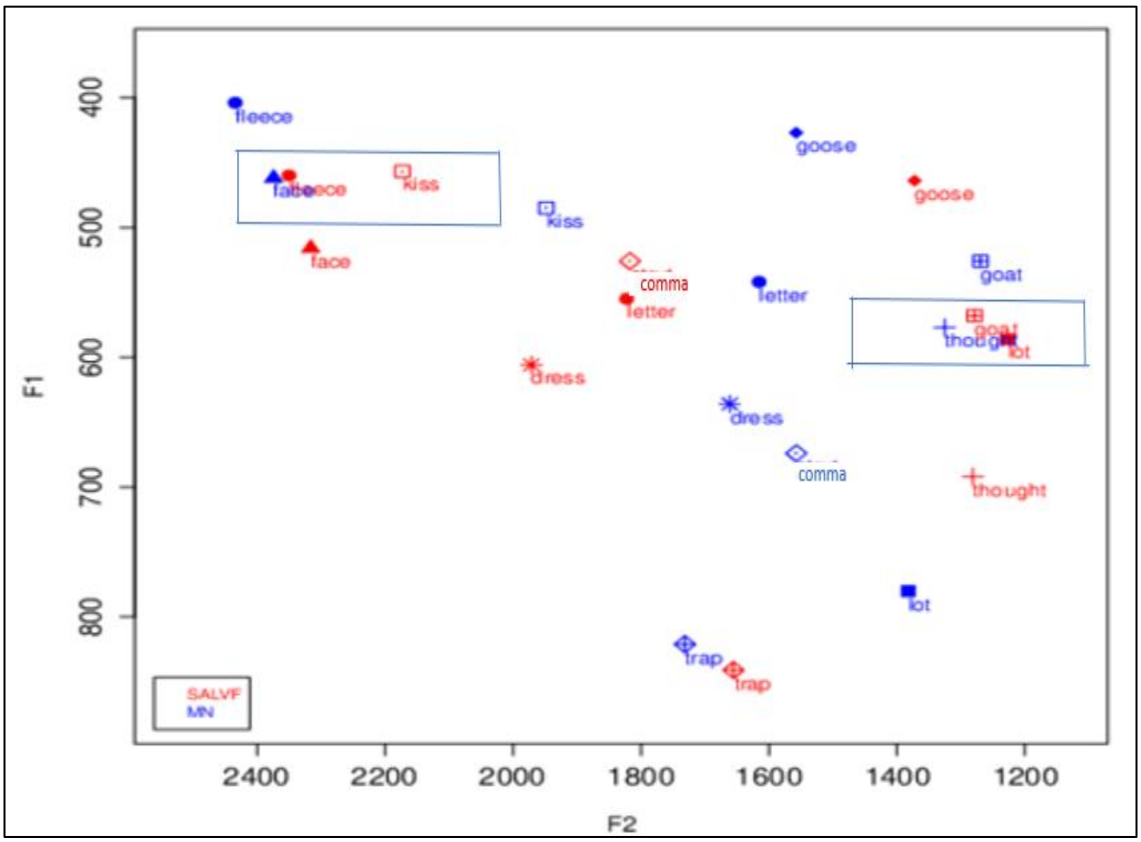
As in the internal masking analysis, focus is given to the complete external masking findings. For female Salvadoran vowels, only two sets of vowels are problematic for MN hearers. The first set is the *kiss* vowel [ɪ] (457 Hz) and the *face* vowel [e] (462 Hz). When female Salvadoran speakers produce the *kiss* sound [ɪ], it masks the female MN *face* sound [e] completely because the acoustic distance is only 5 Hz. With an RFL of 80%, this makes it completely unintelligible. For example, if a female Salvadoran speaker says <fill>, it will be misperceived as <fail> by a MN hearer. There is also an instance with moderate masking. When female Salvadoran speakers produce the *fleece* sound [i] (460 Hz), it masks the female MN *kiss* sound [I] (485 Hz) moderately because the acoustic distance is only 25 Hz. If a female Salvadoran speaker says <cheap>, it will be misperceived as <chip> by a MN hearer.

The second example of complete masking is the *thought* vowel [ɔ] and *goat* vowel [o] vowel. As back vowels, the *goat* vowel [o] (568 Hz) produced by female Salvadoran speakers masks the *thought* vowel [ɔ] (577 Hz) produced by MN speakers. The acoustic distance between them is 9 Hz. Since the RFL between them is 88%, masking results in poor intelligibility. If a female Salvadoran speaker says the word <so>, it might be heard by MN hearers as <saw>. It is interesting to note that this same pair of vowels causes intelligibility issues in the study of Salvadoran-accented vowels in isolation (Peña, 2019).

The rest of the vowel sounds have an acoustic distance of 60 Hz or higher, which suggests that there is no masking. Figure 3.2 presents the vowels that have intelligibility issues.

Figure 3.2

External Masking for Female SALV and MN Vowels



Overall, the intelligibility of female Salvadoran vowels regarding external masking with their MN counterparts is very robust. Most female SALV vowels can be distinguished with no intelligibility issues. Eight of their 11 (72%) vowels are completely distinguishable from each other with more than 60 Hz of distance between them. The *kiss* vowel [ɪ] (457 Hz) leads to poor intelligibility because of a complete masking with the *face* vowel [e] (462 Hz) as they have an acoustic difference of only 5 Hz and an associated RFL of 80%. The *goat* vowel [o] (568 Hz) and the *thought* vowel [ɔ] also cause poor intelligibility, with only 9 Hz of acoustic difference and an associated RFL of 88%.

Male Participants

This part of the chapter will be used to make a vowel comparison between the vowels of the male SALV participants and the male MN speakers. A Vowel comparison and an external masking and intelligibility analysis are presented.

Vowel Comparison

This part of the chapter focuses on highlighting the main similarities and differences between the male Salvadoran English speakers and the male Minnesotans. For F1, the *lot* vowel [ɑ], the *goat* vowel [o], and the *comma* vowel [ə] have the greatest differences, with 161 Hz, 122 Hz, and 110 Hz, respectively. These differences mean that they are produced the most dissimilarly. For F2, the *comma* vowel [ə], the *kiss vowel* [ɪ], and the *goat vowel* [o] show the greatest acoustic differences. Table 3.3 lists the vowels from both groups of speakers.

Table 3.3

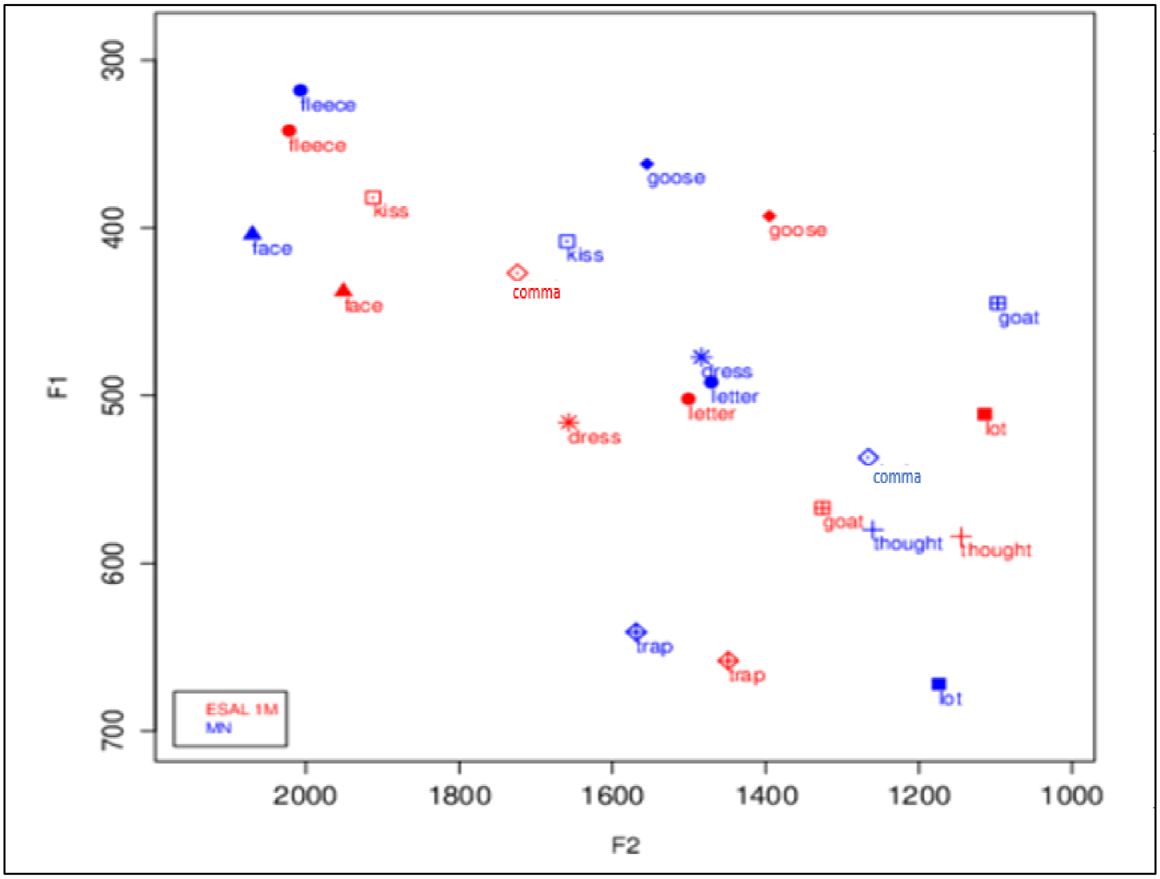
F1 and F2 Data for Male SALV and MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
Vowel	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
F1											
Male SALV	342	382	438	516	658	511	584	567	393	427	502
Male MN	318	408	404	477	641	672	580	445	362	537	492
F1 difference	**24**	**26**	**34**	**39**	**17**	**161**	**4**	**122**	**31**	**110**	**10**
Male SALV	2022	1912	1951	1657	1449	1114	1145	1326	1395	1724	1501
Male MN	2007	1659	2070	1484	1569	1174	1260	1097	1555	1266	1471
F2 difference	**15**	**253**	**119**	**173**	**120**	**60**	**115**	**229**	**160**	**458**	**30**

By analyzing the information in the table above, some similarities can be highlighted. Both male SALV and MN speakers produce the *fleece* vowel [i] (SALV: 342 Hz vs MN: 318 Hz) as a high fronted phoneme. However, this high vowel produced by male MN speakers is higher by 24 Hz. This makes it the highest vowel produced by MN males. The *trap* vowel [æ] (658 Hz) is the lowest sound produced by SALV male participants, and the *lot* vowel [ɑ] (672 Hz) is the lowest vowel produced by male MN participants. The *thought* vowel [ɔ] produced by male SALV (584 Hz) and MN (580 Hz) is also similar, with an acoustic difference of 4 Hz. Moreover, the *letter* vowel [ɚ] and the *trap* vowel [æ] produced by male SALV speakers are also close these produced by their MN counterparts with 10 Hz and 17 Hz of acoustic difference, respectively. To give a clearer picture of all remaining vowels, an acoustic vowel space is provided in Figure 3.3.

Figure 3.3

Comparative Vowel Space for Male SALV and MN Speakers



More similarities between male Salvadoran English and male MN vowels are found in all three regions (front, central, and back). The *face* vowel [e] is fronted-mid in both male Salvadoran vowels and male MN vowels. The *letter* vowel [ɚ] is a central-mid vowel in both groups as well. Also, the *goose* vowel [u] is the only central-high vowel for both male SALV and MN vowels.

There are also differences that can be emphasized. The *lot* vowel [ɑ] is a backed-mid vowel in male MN English, but it is a backed-low vowel in male Salvadoran English. Moreover, the *dress* vowel [ɛ] is a central-mid vowel in MN English; however, it is a fronted-mid vowel in male Salvadoran English. The *kiss* vowel [ɪ] in male MN English is fronted-mid, but it has risen to become a fronted-high vowel in male Salvadoran English. Another difference can be found in the *comma* vowel [ə] as it is a central-mid vowel in male MN English but a fronted-mid vowel in male Salvadoran English. The last noticeable difference is in the *goat* vowel [o] as it is a backed-mid vowel in male MN English but a central-mid vowel in male Salvadoran English.

External Masking and Intelligibility

As stated before, when the acoustic distance between two different phonemes is less than 20 Hz, they are considered to have complete external masking. Table 3.4 below presents the external masking measurements of the male Salvadoran participants compared to the male MN participants. In this table, the first vowel in each row is produced by Salvadoran speakers, while in the second is by Minnesota speakers.

Table 3.4

External Masking and Intelligibility of Male SALV and Male MN Vowels

Vowel Pairs	F1 Distance	External Masking Levels		RFL		Intelligibility Rating
[i] (342 Hz) vs. [ɪ] (408 Hz)	66 Hz	No masking		95%		Poor intelligibility
[ɪ] (382 Hz) vs. [e] (404 Hz)	22 Hz	Moderate masking		80%		Poor intelligibility
[e] (438 Hz) vs. [ɛ] (477 Hz)	39 Hz	Moderate masking		53%		Mediocre intelligibility
[ɛ] (516 Hz) vs. [æ] (641 Hz)	125 Hz	No masking		53%		Mediocre intelligibility
[u] (393 Hz) vs. [o] (445 Hz)	52 Hz	No masking		51%		Good intelligibility
[o] (567 Hz) vs. [ɔ] (580 Hz)	**13 Hz**	**Complete masking**		**88%**		**Poor intelligibility**
[ɔ] (584 Hz) vs. [ɑ] (672 Hz)	88 Hz	No masking		26%		Fair intelligibility
[æ] (658 Hz) vs. [ə] (537 Hz)	121 Hz	No masking		68%		Mediocre intelligibility
[ə] (427 Hz) vs. [ɑ] (672 Hz)	245 Hz	No masking		65%		Mediocre intelligibility
[æ] (658 Hz) vs. [ɑ] (672 Hz)	**14 Hz**	**Complete masking**		**76%**		**Poor intelligibility**

Focus is given to the complete external masking findings with RFLs that cause poor intelligibility. For male Salvadoran vowels, only two sets of vowels are problematic for MN hearers. The first set of vowels that mask each other completely is the *goat* vowel [o] (567 Hz) and the *thought* vowel [ɔ] (580 Hz). The acoustic distance between them is only 13 Hz. With an RFL of 88%, this leads to poor intelligibility. For example, if a male Salvadoran speaker says <so>, it will be misperceived as <saw> by a MN hearer.

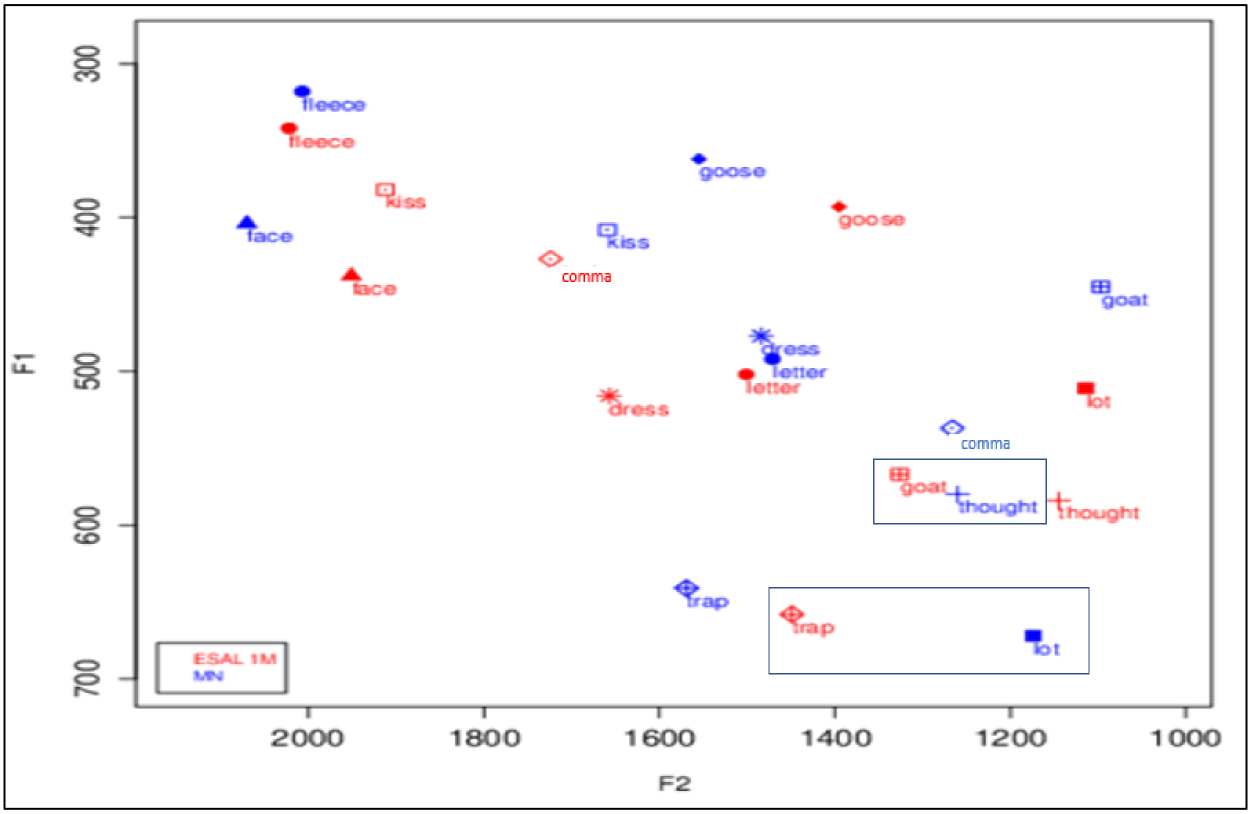
The second instance is between the *trap* vowel [æ] (658 Hz) and the *lot* vowel [ɑ] (672 Hz), as the acoustic difference between them is 14 Hz. The RFL between them is 78%. Masking between them also leads to poor intelligibility. When a male Salvadoran speaker says <bat>, it will be misperceived as <bought> by a MN hearer.

There are also instances of moderate masking between vowels. The *kiss* vowel [ɪ] and the *face* [e] vowel have an acoustic distance of 22 Hz. Although the masking is not complete, there is still moderate masking with a RFL of 80%. Another set of vowels with moderate intelligibility is the one formed by the *face* vowel [e] and the *dress* vowel [ɛ], with an acoustic difference of 39 Hz. When a male Salvadoran speaker says <wait>, it will be misperceived as <wet> by a MN hearer. These results are different from the study carried out by Peña (2019), where there are intelligibility issues between the *fleece* vowel [i] and the *kiss* vowel [ɪ].

The rest of the vowel sounds have an acoustic distance of 60 Hz or higher, which means that there is no masking. Figure 3.4 presents the vowels with intelligibility issues.

Figure 3.4

External Masking for Male SALV and MN Vowels



Overall, the intelligibility of male Salvadoran vowels regarding external masking with their MN counterparts is very robust. Most of their vowels can be distinguished with no intelligibility issues. Eight of the eleven (72%) vowels are completely distinguishable from each other with more than 60 Hz of distance between them. The *goat* vowel [o] (567 Hz) leads to poor intelligibility because of a complete masking with the *thought* vowel [ɔ] (580 Hz), with an acoustic difference of only 13 Hz and an associated RFL of 88%. The *trap* vowel [æ] (658 Hz) and the *lot* vowel [ɑ] (672 Hz) also cause poor intelligibility, with only 14 Hz of acoustic difference and an associated RFL of 76%. It is fascinating to highlight that the *goat* vowel [o] and the *thought* vowel [ɔ] present intelligibility issues for both male and female Salvadoran speakers.

Summary

Although both male and female participants in this study speak Spanish as a native language and come from the same country, they mask different vowels (except for the *goat* [o] vowel and the *thought* vowel [ɔ]) when compared to their MN counterparts. On one hand, Salvadoran female participants pronounce the *kiss* vowel [ɪ] (457 Hz) similarly to the *face* vowel (462 Hz) produced by female MN speakers. There are only 5 Hz of acoustic difference, which leads to intelligibility issues. Similarly, the *goat* vowel (568 Hz) produced by female Salvadoran speakers is like the *thought* vowel (577 Hz) produced by female MN speakers. The acoustic difference is only 9 Hz, leading to intelligibility issues. On the other hand, Salvadoran male participants mask three pairs of vowels when compared to their MN counterparts. The first pair of vowels with intelligibility issues is the one formed by the *goat* vowel [o] (567 Hz) produced by Salvadoran male speakers and the *thought* vowel [ɔ] (580 Hz) produced by MN male speakers with an acoustic difference of 13 Hz. It is interesting to notice that this same pair of vowels is masked by female and male speakers when compared to their MN counterparts. The second set of vowels with intelligibility issues is the *trap* vowel [æ] (658 Hz) produced by Salvadoran male speakers and the *lot* vowel [ɑ] (672 Hz) produced by MN male speakers, with an acoustic difference of 14 Hz. In both pairs of vowels, the masking is absolute. There is also an occurrence where the masking in the pair of vowels is almost absolute with 22 Hz of acoustic difference. Those vowels are the *kiss* vowel (382 Hz) produced by Salvadoran male participants and the *face* vowel (404 Hz) produced by MN male speakers.

Chapter IV: Pedagogical Implications and Applications

Introduction

Pedagogical implications and applications are the focus of this chapter. It is divided into two sections addressing each of the intelligibility issues found first in the internal masking analysis and then the external masking analysis. Also, the chapter includes a section to discuss pedagogical implications. The intelligibility issues that will be addressed in the chapter are the *fleece* [i] and *kiss* [e] vowels, the *goat* [o] and *thought* [ɔ] vowels, and the *trap* [a] and *lot* [ɑ] vowels. This chapter provides an insight into pedagogical steps educators and participants should consider when teaching English to Salvadoran learners. ESL classrooms usually have a mixture of male and female students, so this chapter is not structured according to gender.

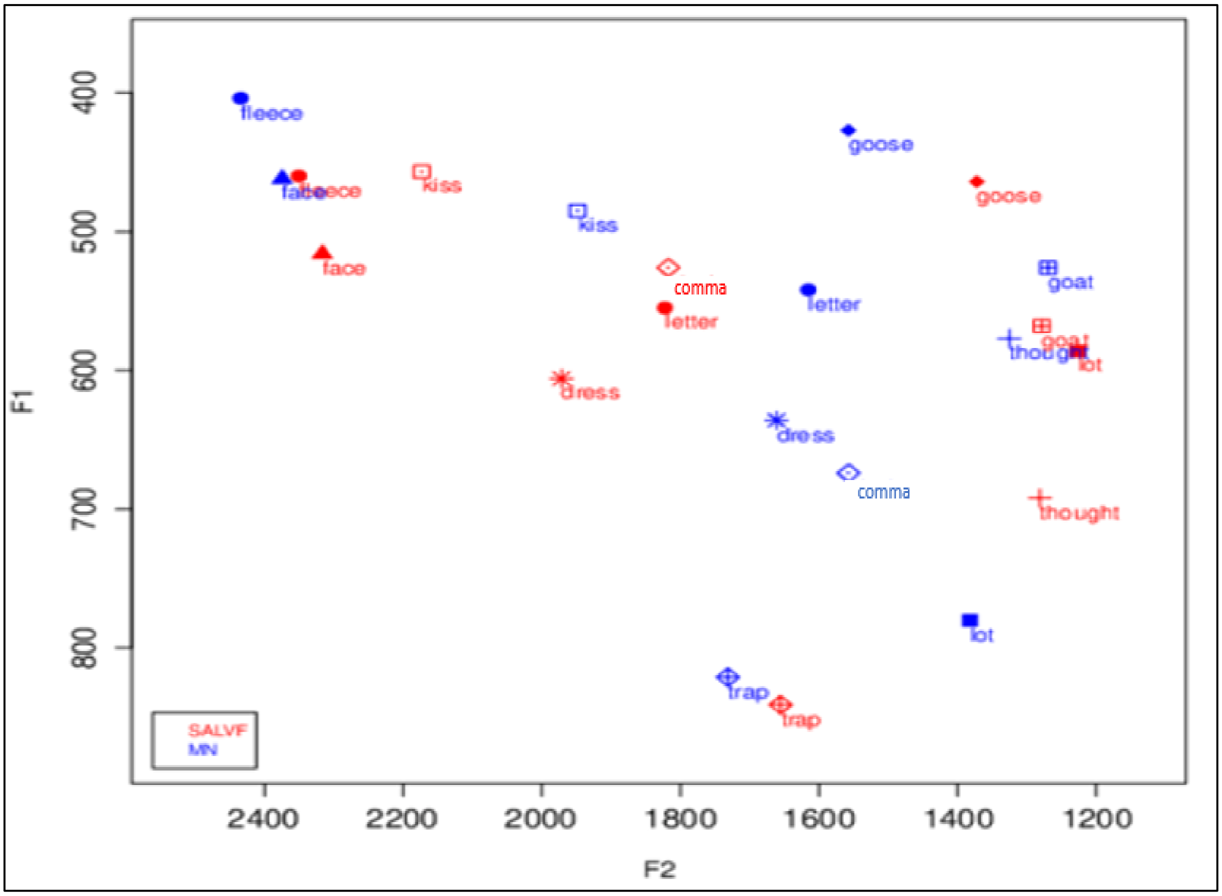
Implications for Internal Masking Analysis

The phonetic characteristics of English vowels produced by male and female Salvadoran speakers were introduced in Chapters II and III. According to the internal masking analysis, absolute masking occurs between two pairs of vowels: [i] vs. [ɪ], and [o] versus [ɔ]. Masking occurrence between these vowels leads to a poor level of intelligibility. The first complete internal masking is with a fronted vowel. The acoustic distance between the *fleece* vowel [i] (460 Hz) and the *kiss* vowel [ɪ] (457 Hz) is only 3 Hz, which indicates complete masking. With an RFL of 95%, the intelligibility is poor. The second complete internal masking is between the SALV *goat* vowel [o] (567 Hz) and the MN *though* vowel [ɔ] (580 Hz) with an acoustic difference of only 13 Hz. With an RFL at 88%, the intelligibility is poor.

Pedagogical Proposal for Differentiating [i] and [ɪ]. There is poor intelligibility due to complete masking between the *kiss* vowel [ɪ] and the *fleece* vowel *[i]*. Figure 4.1 shows the vowel changes that are needed to fix this intelligibility issue.

Figure 4.1

Vowel Movement Needed to Fix Intelligibility Issues Between the Kiss Vowel [ɪ] and the Face Vowel [e]



Speakers should focus on the level of mouth aperture. To raise their *fleece* vowel [i], speakers should be guided in producing it with a smaller mouth aperture. This step will have a direct impact on reducing their F1so it becomes closer to MN one. The SALV *fleece* vowel [i] has a F1 mean of 460 Hz and the SALV *face* vowel [e] has a mean F1 of 516 Hz. Salvadoran speakers should practice with minimal pairs until their measurements reach at least 404 Hz and 462 Hz, respectively. Using minimal pairs of the *fleece* vowel [i], the *kiss* vowel [ɪ], and the *face* vowel [e] is an efficient way to correct vowel masking and increase the acoustic distance needed

(≥ 60 Hz). Figure 4.2 shows the tongue position needed to pronounce each vowel accurately. The minimal pairs in Tables 4.1, 4.2, and 4.3 give a series of such pairs for the *fleece*, *kiss* [ɪ], and *face* [e] vowels.

Figure 4.2

Tongue Position for the Fleece [i], Kiss [ɪ], and Face [e] Vowels (adapted from The Virtual Linguistics Campus (2013) and Ubc VISIBLE SPEECH (2015)

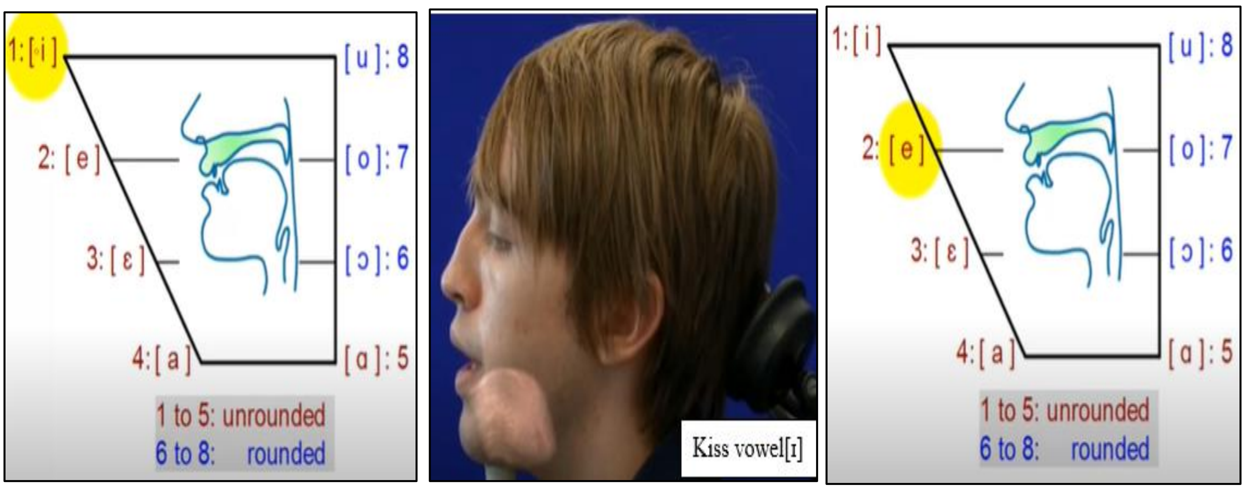


Table 4.1

Minimal Pairs for Fleece [i] and Kiss [ɪ] Vowels

Vowel	Minimal Pairs								
[i]	beat	lead	greed	keep	reason	bead	cheek	peel	seep
[ɪ]	bit	lid	grid	kip	risen	bid	chick	pill	sip

Table 4.2

Minimal Pairs for Kiss *and* Face *[e] Vowels*

Vowel	Minimal Pairs								
[ɪ]	knit	lid	tick	kit	kiss	lit	mill	sill	wit
[e]	Nate	laid	take	Kate	case	late	male	sale	wait

Table 4.3

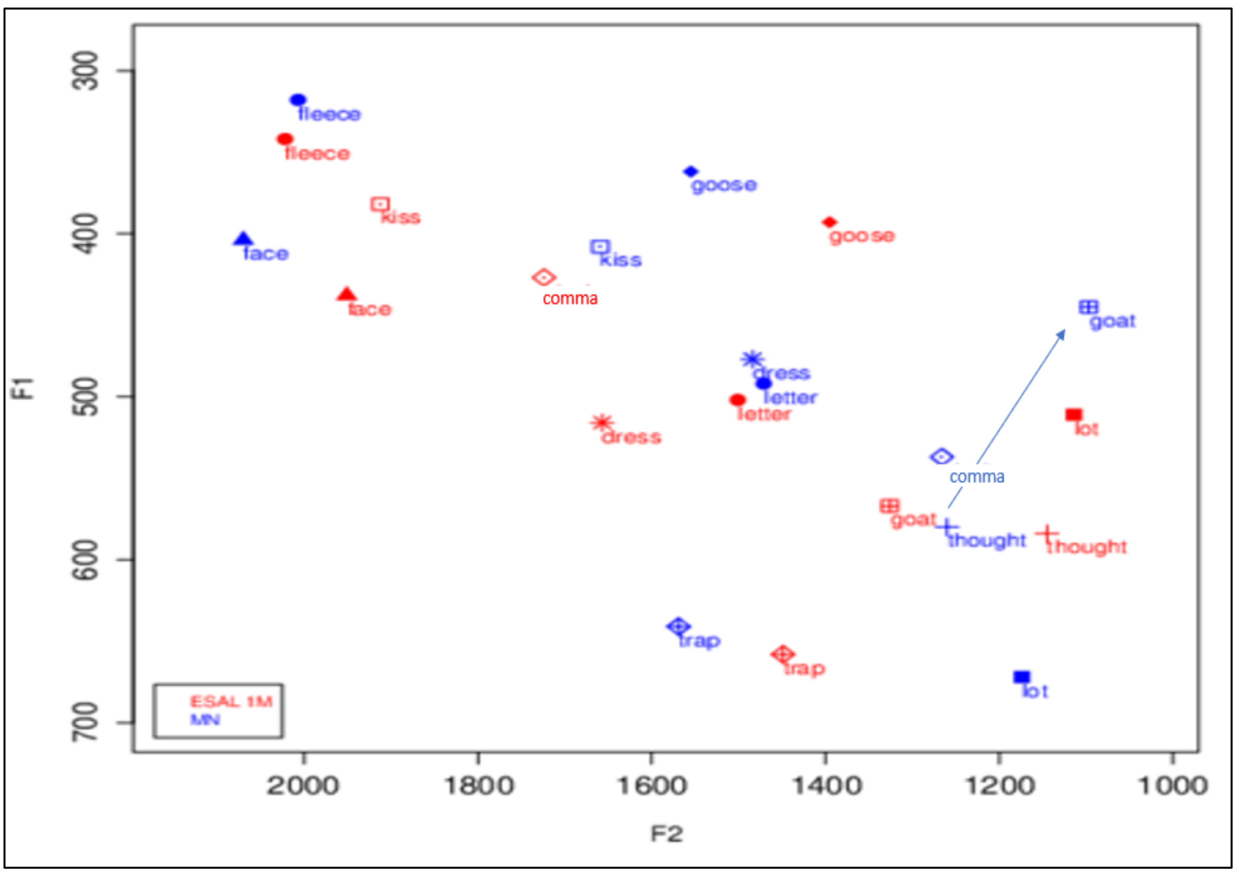
Minimal Pairs for Fleece *[i],* Kiss *[ɪ] and* Face *[e] Vowels*

Vowel	Minimal Pairs					
[i]	beat	dean	lead	bead	meed	deal
[ɪ]	bit	din	lid	bid	mid	dill
[e]	bait	Dane	laid	bade	maid	Dale

Pedagogical Proposal for Differentiating [o] and [ɔ]. The first step is to raise the SALV *goat* vowel [o] by at least 42 Hz. Figure 4.3 shows the vowel changes that are needed to fix this intelligibility issue.

Figure 4.3

Vowel Movement Needed to Fix Intelligibility Issues Between the Goat *Vowel [o] and the* Thought *Vowel [ɔ]*



Speakers should focus on the level of mouth aperture. To raise their *goat* vowel [o], speakers should be guided in producing it with a smaller mouth aperture. This step will have a direct impact on bringing their F1 closer to the MN F1. The SALV *goat* vowel [o] has a F1 mean of 567 Hz. SALV speakers should practice with minimal pairs until their measurement reaches at least 445 Hz. Using minimal pairs of the *goat* vowel [o] and the *thought* vowel [ɔ] is an efficient way to correct vowel masking and increase the acoustic distance needed (≥ 60 Hz). Figure 4.4 shows the tongue position needed to pronounce each vowel accurately, and the minimal pairs in Tables 4.4, 4.5, and 4.6 give a series of such pairs for the *fleece [i]*, the *goat* [o] and the *thought* [ɔ] vowels.

Figure 4.4

Tongue Position for Goat *[o] and* Thought *[ɔ]* (adapted from The Virtual Linguistics Campus, 2013)

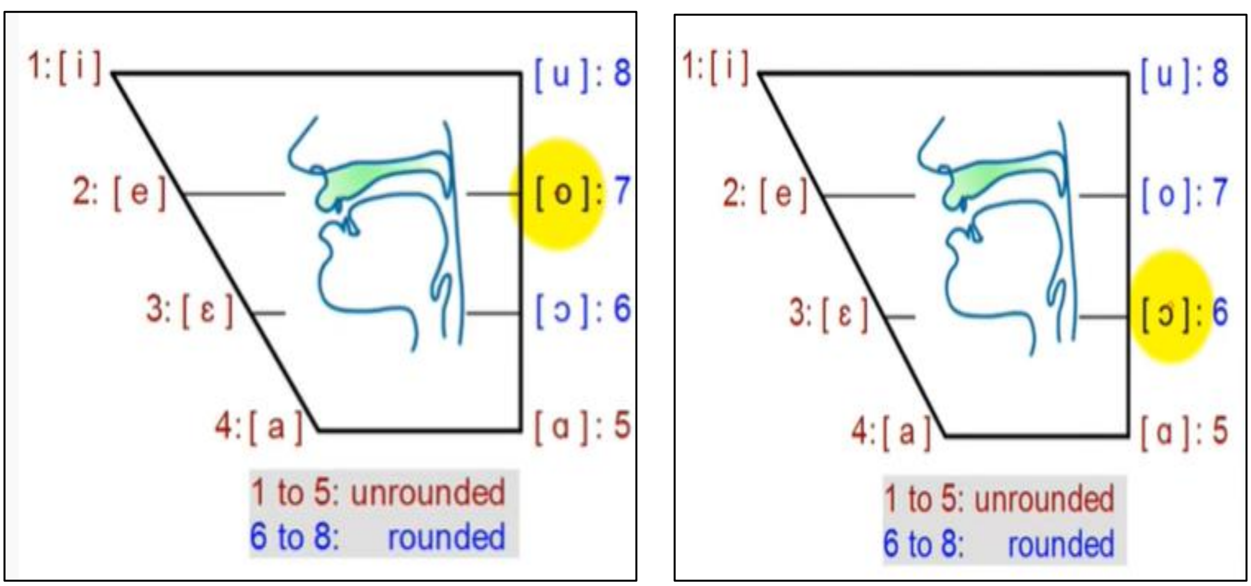


Table 4.4

Minimal Pairs for Goat *[o] and* Thought *[ɔ] Vowels*

Vowel								
[o]	boat	coke	know	mow	so	poke	foe	flow
[ɔ]	bought	cock	gnaw	maw	saw	poke	fa	flaw

Table 4.5

Minimal Pairs for Goat *[o] and* Lot *[a] Vowels*

Vowel	Minimal Pairs							
[o]	note	won't	goat	hope	cope	own	coast	road	soap
[ɑ]	not	want	got	hop	cop	on	cost	rod	sop

Table 4.6

Minimal Pairs for Lot *[a]and* Thought *Vowels*

Vowel	Minimal Pairs								
[ɑ]	cot	fox	tock	tot	wok	stock	sod	mall	chock
[ɔ]	caught	forks	talk	taught	walk	stalk	sawed	maul	chalk

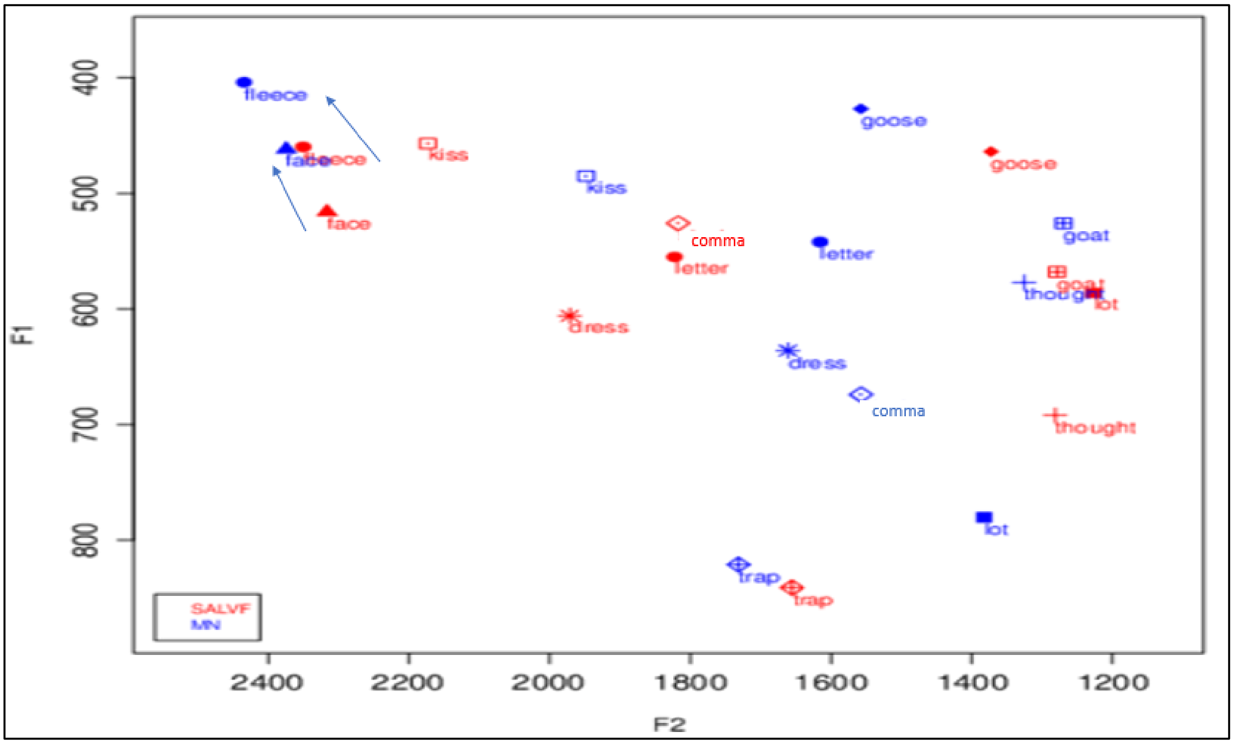
Implications for External Masking Analysis

The measurements also indicate that MN speakers of English are likely to misunderstand Salvadoran-accented English. According to the internal masking analysis, absolute masking occurs between two pairs of vowels: [ɪ] vs. [e], and [**æ**] versus [ɑ]. The first complete external masking issue is between [ɪ] vs. [e]. The acoustic difference between the *kiss* vowel [ɪ] (457 Hz) and the *face* vowel[e] (462 Hz) is 5 Hz. Since the RFL between them is 80%, masking results in poor intelligibility. The second complete external masking is between the *trap* vowel [æ] (658 Hz) and the *lot* vowel [ɑ] (672 Hz), as the acoustic difference between them is 14 Hz, and the RFL between them is 78%. Masking between them also leads to poor intelligibility.

Pedagogical Proposal for Differentiating [ɪ] and [e]. The first step is to raise the SALV *face* vowel [e] and *fleece* vowel [i]. Figure 4.5 shows the vowel changes that are needed to fix this intelligibility issue.

Figure 4.5

Vowel Movement Needed to Fix Intelligibility Issues Between the Kiss *Vowel [ɪ] and the* Face *Vowel [e]*



Speakers should focus on the level of mouth aperture. To raise their *fleece* vowel [i], speakers should be guided in producing it with a smaller mouth aperture. The *face* vowel [e] also needs to be raised. These steps will have a direct impact on bringing their F1 closer to that of MN speakers. The SALV *fleece* vowel [i] has a mean F1 of 460 Hz, and the SALV *face* vowel [e] has a mean F1 of 516 Hz. Salvadoran speakers should practice with minimal pairs until their measurements reach at least 404 Hz and 462 Hz, respectively. Using minimal pairs of the *fleece* vowel [i], the *kiss* vowel [ɪ], and the *face* vowel [e] is an efficient way to correct vowel masking and increase the acoustic distance needed (≥ 60 Hz). Figure 4.6 shows the tongue position needed to pronounce each vowel accurately, and the minimal pairs in Tables 4.7, 4.8, and 4.9 give a series of such pairs for the *fleece*, the *kiss* [ɪ], and the *face* [e] vowels.

Figure 4.6

Tongue Position for Fleece [i], Kiss [ɪ], and Face [e] Vowels (adapted from The Virtual Linguistics Campus (2013) and Ubc VISIBLE SPEECH (2015)

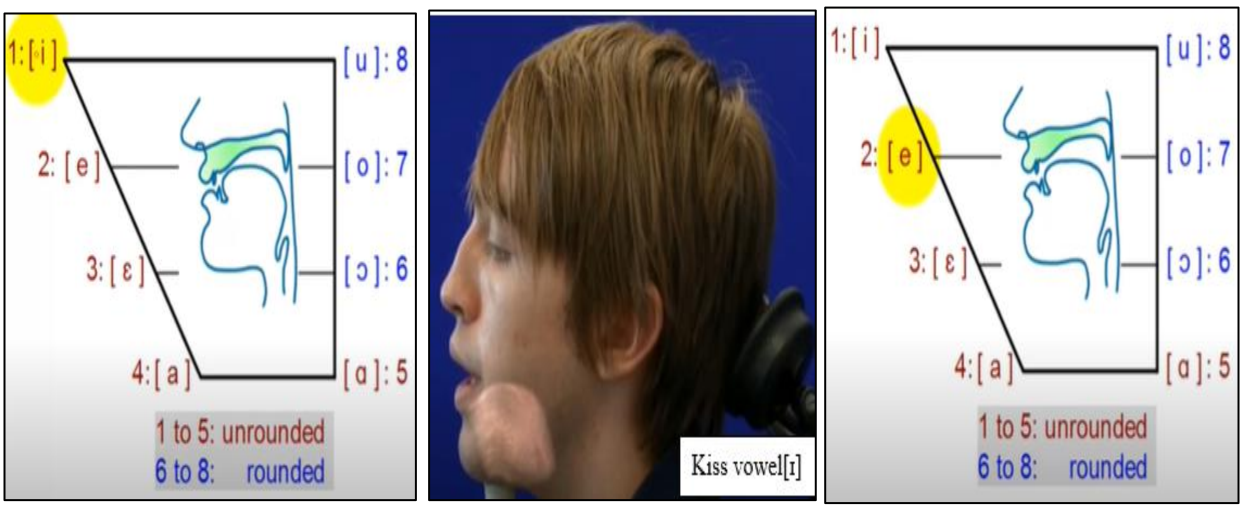


Table 4.7

Minimal Pairs for Fleece *[i] and* Kiss *[ɪ] Vowels*

Vowel	Minimal Pairs								
[i]	Beat	lead	greed	keep	reason	bead	cheek	peel	seep
[ɪ]	Bit	lid	grid	kip	risen	bid	chick	pill	sip

Table 4.8

Minimal Pairs for Kiss [ɪ] and Face [e] Vowels

Vowel	Minimal Pairs								
[ɪ]	knit	lid	tick	kit	kiss	lit	mill	sill	wit
[e]	Nate	laid	take	Kate	case	late	male	sale	wait

Table 4.9

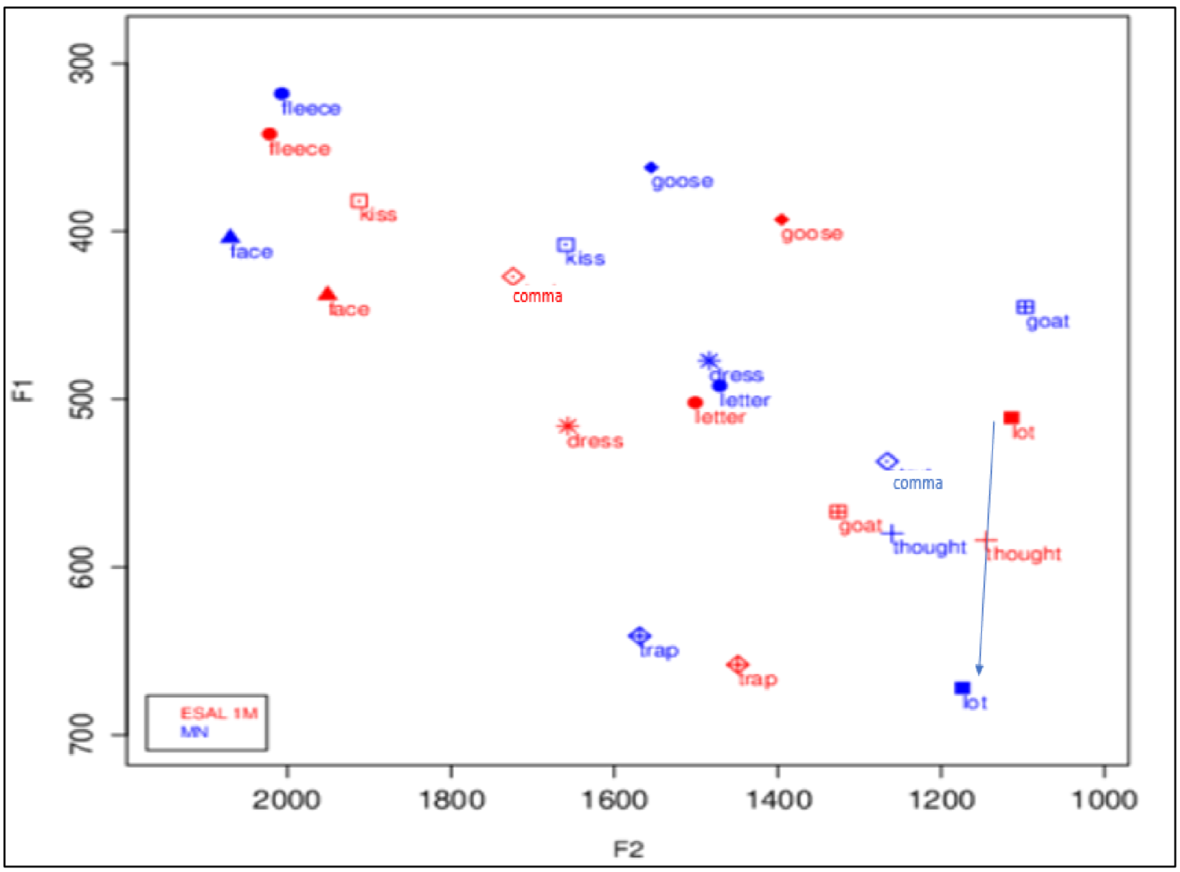
Minimal Pairs for Fleece *[i],* Kiss *[ɪ] and* Face *[e] Vowels*

Vowel	Minimal Pairs					
[i]	beat	dean	lead	bead	meed	deal
[ɪ]	bit	din	lid	bid	mid	dill
[e]	bait	Dane	laid	bade	maid	Dale

Pedagogical Proposal for Differentiating [æ] and [ɑ]. The proposal is to lower the SALV *lot* vowel [ɑ] by at least 161 Hz. Figure 4.7 shows the vowel change that is needed to fix this intelligibility issue.

Figure 4.7

Vowel Movement Needed to Fix Intelligibility Issues between the Trap *vowel [æ] and the* Lot *Vowel [ɑ]*



Speakers should focus on the level of mouth aperture. To lower the *lot* vowel [ɑ], speakers should be guided in producing them with a bigger mouth aperture. This step will have a direct impact on increasing their F1 closer. The SALV *lot* vowel [ɑ] has a mean F1 of 511 Hz. Salvadoran speakers should practice with minimal pairs until their measurement reaches at least 672 Hz. Using minimal pairs of the *trap* [æ] and the *lot* vowel [ɑ] is an efficient way to correct vowel masking and increase the acoustic distance needed (≥ 60 Hz). Figure 4.8 shows the tongue position needed to pronounce each vowel accurately; the minimal pairs in Table 4.10 gives a series of such pairs for the *trap* [æ] and the *lot* [ɑ] vowels.

Figure 4.8

Tongue Position for Trap [æ] and Lot [a] vowels (adapted from The Virtual Linguistics Campus (2013)

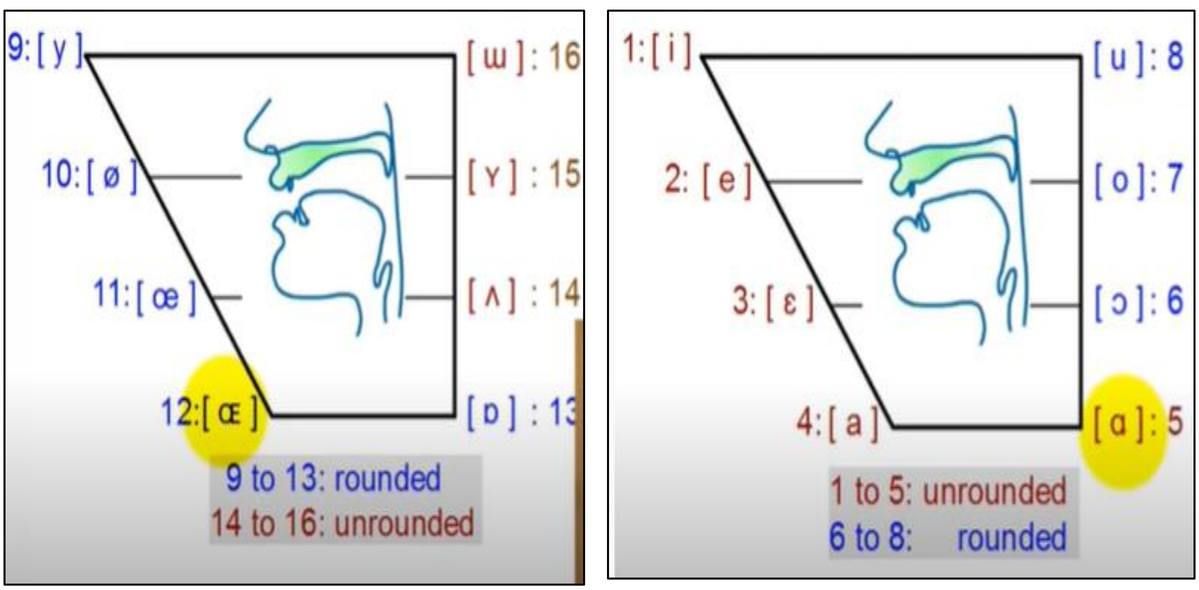


Table 4.10

Minimal Pairs for Trap *[æ] and* Lot *[ɑ] Vowels*

Vowel	Minimal Pairs							
[æ]	hat	cap	sad	rat	band	ham	lack	last	cast
[ɑ]	hot	cop	sod	rot	bond	harm	lock	lost	cost

Pedagogical Applications

Schmidt (2010) states that learners must notice the linguistic features and make conscious comparisons between their own output and the target language input. The Noticing Hypothesis should be applied to teaching pronunciation to second language learners. It can be beneficial for students to be able to notice the differences between the sounds they produce and the sounds produced by native English speakers.

This study can help ESL/EFL educators working with Salvadorans and individual learners who want to improve their intelligibility. First, educators can use the data in this study to address intelligibility issues in the classroom. This study includes data for male and female participants, and educators can use this date to teach pronunciation and improve the intelligibility of the learners. According to the data in this study, educators should focus on the pair of vowels formed by the *fleece* vowel [i] and *face* vowel [e] and that formed by the *goat* vowel [o] and the *thought* vowel [ɔ] when working with female Salvadoran learners. When working with male Salvadoran learners, educators should pay attention to the pair of vowels formed by the *goat* vowel [o] and the *thought* vowel [ɔ]. This study also offers an opportunity for Salvadoran English learners to find out what vowels Salvadorans usually have issues with. Praat is a software program that is available online for any individual to use, and students can use it to measure their vowels and to compare them to the vowels produced by native speakers. This individual awareness can make students take charge of their speech intelligibility.

Conclusion

This study of vowel intelligibility in running speech offers extensive details regarding L2-accented English of Salvadoran speakers. It provides a detailed analysis of the vowel production that causes intelligibility issues in Salvadoran-spoken English. This work provides great insights for EFL/ESL educators. It also provides crucial data needed to make Salvadoran learners of English aware of their pronunciation and encourage them to focus on intelligibility. With the information collected from Salvadoran English speakers, the research questions can be answered.

Chapter V: Results, Discussion, and Conclusion

This study on vowel intelligibility in running speech provides detailed information on L2 accented English of Salvadoran speakers. It can be used to identify the vowels that Salvadorans pronounce incorrectly, causing severe intelligibility issues.

Research Question #1

How do L2 Salvadoran-accented English vowels compare to those produced in speakers of general American English?

This study includes the vowel spaces of male and female participants separately. Results show that they mask vowels somewhat differently when compared to their MN counterparts. Salvadoran female participants pronounce the *kiss* vowel [ɪ] (457 Hz) similarly to the *face* vowel [e] (462 Hz) produced by female MN speakers. When a female Salvadoran tries to pronounce the word *kiss,* it can be perceived as *case.* There are only 5 Hz of acoustic difference between the two vowels, and this leads to intelligibility issues. Similarly, the *goat* vowel [o] (568 Hz) produced by female Salvadoran speakers is like the *thought* vowel [ɔ] (577 Hz) produced by female MN speakers. When a female Salvadoran tries to pronounce the word /so/, it can be perceived as /*saw/.* The acoustic difference is only 9 Hz, which leads to intelligibility issues. Salvadoran male participants mask three pairs of vowels when compared to their MN counterparts. The first pair of vowels with intelligibility issues is the one formed by the *goat* vowel [o] (567 Hz) produced by Salvadoran male speakers and the *thought* vowel [ɔ] (580 Hz) produced by MN male speakers with an acoustic difference of 13 Hz. It is interesting to note that this same pair of vowels is masked by female and male speakers when compared to their MN counterparts. The second set of vowels with intelligibility issues is the *trap* vowel [æ] (658 Hz) produced by Salvadoran male speakers and the *lot* vowel [ɑ] (672 Hz) produced by MN male speakers, with an acoustic difference of 14 Hz. In both pairs of vowels, the masking is absolute. There is also an occurrence where the masking in a pair of vowels is almost absolute, with 22 Hz of acoustic difference. These are the *kiss* vowel [ɪ] (382 Hz) produced by Salvadoran male participants and the *face* vowel [e] (404 Hz) produced by MN male speakers. Again, this same pair of vowels is also problematic for both male and female participants.

Research Question #2 and #3

Are there vowels produced by Salvadoran-accented English that cause intelligibility issues in running speech?

What are the L2 Salvadoran-accented English vowels that may cause intelligibility issues when interacting with other English speakers?

The simple answer for question #2 is yes, there are vowels produced by Salvadoran-accented English that cause intelligibility issues. The first intelligibility issue is between the *kiss* vowel [ɪ] and the *face* vowel [e]. When Salvadorans try to pronounce the word *lit*, it can be perceived as *late.* This intelligibility issue may lead to unnecessary confusion. The second intelligibility issue is between the *goat* vowel [o] and the *thought* vowel [ɔ]. When Salvadorans try to pronounce the word *boat*, it can be perceived as *bought.* The final intelligibility issue is between the *trap* vowel [æ] and the *lot* vowel. [ɑ]. It is interesting to notice that lax vowels seem to be particularly problematic for Salvadorans (the *kiss* vowel [ɪ] and the *trap* vowel [æ]).

Research Question #4

Is there any difference in intelligibility between Salvadoran-accented vowels in isolation and Salvadoran-accented vowels in running speech?

Peña (2019) studied Salvadoran-accented vowels in isolation, and this study is about Salvadoran-accented vowels in running speech. Peña's study reveals a total of two intelligibility issues: the *thought* vowel [ɔ] vs the *goat* vowel [o] and the *fleece* vowel [i] vs the *kiss* vowel [ɪ]. The current study reveals three main intelligibility issues: the *kiss* vowel [ɪ] vs. the *face* vowel [e], the *goat* vowel [o] vs. the *thought* [ɔ] vowel, and the *trap* vowel [æ] vs. the *lot* vowel [ɑ]. When analyzing Salvadoran-accented vowels in running speech, more intelligibility issues can be found than with vowels in isolation.

One of the main similarities found in both studies is the existence of intelligibility issues between the *goat* vowel [o] and the *thought* vowel [ɔ]. This is an issue for Salvadoran-accented English in both isolated vowels and running speech. Another important similarity can be found among the *fleece* [i], *kiss* [ɪ], and *face* [e] vowels. In isolated vowels, there are intelligibility issues between the *fleece* vowel [i] and the *kiss* vowel [ɪ]. With vowels in running speech, there are intelligibility issues between the *kiss* vowel [ɪ] and the *face* vowel [e]. The common factor is the *kiss* vowel [ɪ]. The existence of only one phoneme for the vowel "i" in Spanish can cause Salvadorans to have difficulties pronouncing the *kiss* vowel [ɪ] and the *fleece* [i] vowels differently.

The main difference between the study of vowels in isolation and this study on vowels in running speech is in the *trap* vowel [æ] and the *lot* vowel [ɑ]. With vowels in isolation, these vowels do not present intelligibility issues. However, there is an intelligibility issue when vowels are analyzed in running speech. This is an issue for male participants exclusively. These two studies complement each other, and the data found in them should be a guide to teach pronunciation using acoustic phonetics to motivate Salvadorans to focus on intelligibility.

Future Research

This study complements Peña’s (2019) study on Salvadoran-accented vowels in isolation. With both studies taken together, it is easier to have a more complete picture of the production of vowels by Salvadorans. More research can be conducted to determine accurately the production of Spanish vowels by Salvadoran speakers and establish possible correlations with the production of English vowels. These studies also open the door for future studies on the production of consonants by Salvadorans. Such a study would help ESL and EFL educators to have a better idea of the pronunciation issues that Salvadorans commonly face, and it would provide ESL/EFL teachers, linguists, and educators with a complete picture of Salvadoran-accented English.

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Appendix A: JND Thresholds for Acoustic Correlates

The following table provides "the main reference levels/absolute thresholds/Just Noticeable Differences (JNDs)" (Koffi, 2019. p. 56).

	Segments/Suprasegments	Acoustic Correlates	JND Thresholds
Vowels			
1.	Vowels	F1	> 60 Hz
2.	Vowels	F2	≥ 200 Hz
3.	Vowels	F3	≥ 400 Hz
4.	Vowels	F4	≥ 600 Hz
Consonants			
1.	Stops	Voice Onset Time (VOT)	≥ 25, 34, 42 ms
2.	Fricatives and affricates	Intensity	≥ 3 dB
3.	Nasals	F2 for [m] and [n]	≥ 200 Hz
4.	Nasals	F3 for [n] and [ŋ]	≥ 400 Hz
5.	Approximants	F3	≥ 400 Hz
6.	Voicing ratios	Length in milliseconds	40/60
Suprasegmentals			
1.	Stress	F0/Pitch	≥ 1 Hz
2.	Intensity	Intensity	≥ 3dB
3.	Duration	Length in milliseconds	≥ 10 ms/ ≥ 17 ms
4.	Duration of σ	In conversation/reading	200 ms
5.	Duration of a word	In conversation/reading	200 to 600 ms
6.	Duration of a phrase	In conversation/reading	1,000 to 3,000 ms

This Just Noticeable Difference threshold was added from the original table. Fourth formant JND is found in Koffi & Krause (2020, p. 74).

Appendix B: Pitch Features (F0)

The data that was collected for this study is extensive as it includes the data of 25 participants (15 female participants and 10 male participants). However, only the data for F1 and F2 was used to analyze intelligibility. In this study, other acoustic correlates were measured and will be analyzed briefly in this chapter, focusing on F0, F3, F4, intensity, and duration. At the end of the chapter, a summary is included.

Pitch Features (F0)

F0 for Female Salvadoran Speakers of English. Table 5.1 shows pitch measurements for female SALV speakers compared to female MN speakers. Salvadoran speakers have a higher pitch than their MN counterparts. Pitch variation among female SALV speakers is greatest for the *goose* vowel [u] (44 Hz), *fleece* vowel [i] (40.1 Hz) and *face* vowel [e] (37.8 Hz).

Table 5.1

F0 Measurements for Female SALV and Female MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F0 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	202	189	183	186	188	189	173	198	193	178	182
SALV2F	236	224	229	211	223	209	198	251	244	195	209
SALV3F	241	243	217	216	214	223	209	253	329	245	225
SALV4F	198	226	219	208	236	230	218	224	250	233	226
SALV5F	243	192	272	205	215	200	187	230	240	205	215
SALV6F	272	243	215	216	224	221	191	260	230	218	218
SALV7F	254	243	232	242	233	229	229	262	257	215	232
SALV8F	188	202	135	158	159	147	132	164	186	132	172
SALV9F	316	253	249	255	267	250	242	261	304	203	244
SALV10F	244	233	206	216	209	226	217	261	246	214	242
SALV11F	185	160	182	160	180	167	199	206	175	126	179
SALV12F	211	186	175	195	189	182	157	205	210	164	214
SALV13F	161	193	153	187	173	201	168	192	201	170	187
SALV14F	239	233	228	180	180	185	137	224	240	181	190
SALV15F	188	173	163	183	167	168	162	175	180	150	181
Mean	**225**	**213**	**204**	**201**	**204**	**202**	**188**	**224**	**232**	**189**	**208**
St. Deviation	40.1	29.4	37.8	27.0	30.3	28.7	32.7	33.2	44.0	35.5	24.1
MN Female	**205**	**209**	**196**	**209**	**199**	**168**	**190**	**222**	**221**	**196**	**219**

The measurements show that F0 for female SALV vowels is generally higher in pitch than for their female counterparts (63%). Female SALV's *goose* vowel [u] (232 Hz) has the highest pitch of all the inventory. It is higher by 11 Hz than its MN counterpart (221 Hz). The *letter* vowel [ɚ] sound has the lowest standard deviation at 24.1 Hz, and the *goose* vowel [u] has the highest at 44.0 Hz. The average pitch for female SALV vowels is 208 Hz, and the average pitch for MN females is 203 Hz. Female SALV pitch (208 Hz) is higher than MN female pitch (203 Hz) by 5 Hz.

F0 for Male SALV Speakers. Table 5.2 displays F0 measurements for male SALV compared to male MN. Male SALV speakers generally have a higher pitch than male MN speakers. Pitch variation amongst male SALV speakers is greater for the *kiss* vowel [u] (48.6 Hz) and the *goat* vowel [o] (39.8 Hz).

Table 5.2

F0 Measurements for Male SALV and Male MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F0 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	190	161	154	167	163	151	146	172	183	133	169
SALV2M	129	116	110	109	122	112	109	108	118	98	109
SALV3M	126	115	118	90	105	103	85	106	132	114	114
SALV4M	179	180	165	179	174	170	162	180	174	140	164
SALV5M	115	112	108	106	107	109	91	118	118	93	97
SALV6M	140	158	145	134	130	126	130	149	156	133	138
SALV7M	133	171	136	123	133	125	125	229	185	115	144
SALV8M	163	141	148	143	138	131	128	144	154	131	135
SALV9M	127	123	127	122	120	119	124	132	134	109	119
SALV10M	110	10	111	112	110	111	99	107	126	112	103
Mean	**141**	**129**	**132**	**129**	**130**	**126**	**120**	**145**	**148**	**118**	**129**
St. Deviation	27.1	48.6	20.4	27.9	23.1	20.7	24.2	39.8	26.0	15.9	24.9
MN Male	**110**	**107**	**106**	**109**	**101**	**96**	**97**	**126**	**108**	**109**	**118**

Data for F0 male SALV speakers shows that all their vowels are higher in pitch compared to their MN counterparts (100%). The *goat* vowel [o] is the highest pitch occurrence (SALV7M 229 Hz) amongst all the vowel inventory. The *kiss* vowel [ɪ] has the highest standard deviation at 48.6 Hz. The *goose* vowel [u] (148 Hz) has the highest mean pitch for male SALV speakers, and the *comma* vowel [ə] (118 Hz) has the lowest mean pitch. The average pitch for male SALV speakers is 131.5 Hz. The male MN average is 23.6 Hz lower at 107.9 Hz.

Appendix C: Lip Rounding Features (F3)

Lip Rounding Features (F3)

The third formant (F3) is useful to determine lip rounding. Koffi (2016, p. 127) states that F3 values are lower when the lips are rounded and higher when the lips are unrounded. Backstrom (2018) suggests the following boundaries for F3 for female and male speakers. Female lip rounding occurs when F3 is lower than 3000 Hz, and lip retraction happens when F3 values are above 3000 Hz. Male lip rounding happens when F3 is below 2500 Hz, and lip retraction occurs when the value is above 2500 Hz. The acoustic threshold for F3 to distinguish between sounds is a JND ≥ 400 Hz (Appendix A).

F3 for Female SALV Speakers. Table 5.3 shows F3 measurements for female SALV speakers compared to female MN speakers. There are no noticeable differences in lip rounding for these participants compared to female MN speakers. The most rounded vowel for Female SALV speakers is the *letter* vowel (2456 Hz). Similarly, the *letter* vowel (2128 Hz) is the most rounded vowel for female MN speakers.

Table 5.3

F3 Measurements for Female SALV and Female MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F3 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	3297	2840	2770	2867	2694	2649	2722	2823	2784	2764	2129
SALV2F	3002	2938	3069	2780	2890	2595	2723	2955	2804	2902	2470
SALV3F	3106	2970	3062	2386	2867	2819	2686	2842	2669	2089	2367
SALV4F	2882	2904	2831	2538	2548	2670	2555	2910	2861	2395	2095
SALV5F	2940	2833	2894	2592	2396	2614	2399	3066	2773	2865	2358
SALV6F	3058	2916	2982	2767	2687	2781	2637	2851	2705	2810	2354
SALV7F	2926	2982	3482	2678	2545	2393	2579	2761	2778	2859	2549
SALV8F	2567	2638	2462	2319	2735	2397	3124	2477	2476	2708	2139
SALV9F	3038	3039	3135	2853	2909	2857	2777	3242	3144	2865	2614
SALV10F	3159	3100	3104	2857	2668	2793	2845	2914	3136	2980	2965
SALV11F	3226	3059	3178	2972	2774	2662	2783	3034	3427	3129	2630
SALV12F	3269	3111	2887	2456	2730	2883	2730	3186	2730	3201	3111
SALV13F	2656	2812	2849	2553	2456	2739	2364	2849	2898	2787	2271
SALV14F	3003	2672	2941	2460	2129	2505	2409	2775	2679	2507	2146
SALV15F	3127	2972	2979	2778	2867	2833	2673	2995	2873	2911	2646
Mean	**3017**	**2919**	**2975**	**2657**	**2660**	**2679**	**2667**	**2912**	**2849**	**2785**	**2456**
St. Deviation	205.9	141.1	225.9	200.0	214.7	157.6	194.2	185.7	232.8	280.1	302.9
MN Female	**2974**	**2755**	**2838**	**2537**	**2608**	**2575**	**2397**	**2919**	**2794**	**2559**	**2128**

The most lip-retracted sound for female SALV speakers is the *fleece* vowel [i] (3017 Hz). The same vowel is the most lip retracted for female MN speakers with a value of 2974 Hz. The acoustic distance between female SALV and female MN vowels is less than 400 Hz, which shows they have similar degree of lip spread for all the vowels. The female SALV *kiss* vowel [ɪ] is the most stable for F3 with the lowest standard deviation (141.1 Hz) of all vowels. The most unstable for F3 is the *letter* vowel [ɚ] with a standard deviation of 302.9 Hz.

F3 for Male SALV. For male SALV participants, the most lip-retracted vowel is the *goose* vowel [u]. Their most prominent lip rounding occurs for the *letter* vowel [ɚ] (2302 Hz). Table 5.4 shows F3 measurements for male SALV compared to male MN speakers.

Table 5.4

F3 Measurements for Male SALV and Male MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F3 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	2707	2587	2679	2482	2548	2460	2504	2688	2638	2604	2015
SALV2M	2648	2509	2676	2595	2430	2603	2532	2661	2571	2585	2478
SALV3M	2659	2515	2707	2588	2412	2064	2361	3163	2604	2248	2478
SALV4M	2526	2491	2509	2344	2547	2543	2597	2558	2720	2429	2311
SALV5M	2622	2600	2428	2239	2259	2260	2178	2482	2600	2654	2018
SALV6M	2553	2518	2559	2388	2520	2413	2541	2747	2557	2396	1864
SALV7M	2539	2595	2417	2486	2471	2781	2544	2763	2657	2619	2449
SALV8M	2671	2777	2763	2543	2639	2570	2534	2998	2803	2798	2301
SALV9M	2741	2829	2745	2546	2458	2613	2609	2667	2666	2773	2564
SALV10M	3020	3158	3115	2602	2856	3163	2827	3122	3105	3211	2542
Mean	**2669**	**2658**	**2660**	**2481**	**2514**	**2547**	**2523**	**2785**	**2692**	**2632**	**2302**
St. Deviation	142.7	209.7	203.7	121.6	157.2	295.0	167.3	232.3	162.5	264.7	250.5
MN Male	**2711**	**2463**	**2758**	**2627**	**2491**	**2465**	**2599**	**2737**	**2715**	**2516**	**2254**

For male SALV speakers, the *goat* vowel [o] (2785 Hz) is the most lip-retracted of all their inventory. This is a unique of male SALV speakers as their MN counterparts produce the *face* vowel [e] sound as the most lip-retracted at 2758 Hz. The most lip-rounded sounds for male SALV speakers are the *letter* [ɚ] and *dress* [ɛ] vowels, with 2302 Hz and 2481 Hz, respectively. MN male speakers have the most lip-rounded sounds for the *letter* [ɚ] and *kiss* [ɪ] vowels, with 2254 Hz and 2463 Hz, respectively. Overall, there are no noticeable differences in lip rounding for these participants compared to male MN speakers.

Appendix D: Speaker Intrinsic Characteristics (F4)

Speaker Intrinsic Characteristics (F4)

The fourth formant (F4) gives information about individual speaker variations; it does not provide linguistic cues. Ladefoged and Johnson (2015) state that "it is an indicator of the individual's head size." It is expected that not major difference will be noticed in the F4 values of SALV female and male speakers and their MN counterparts. As suggested by Ladefoged and Johnson (2015, p. 222), an average of F4 vowels will be calculated for SALV speakers and compared to the average of MN speakers. The JND threshold of $\geq$ 600 Hz will be used to determine if there are differences between SALV F4 and those of MN speakers.

F4 for Female SALV. Table 5.5 shows F4 measurements for female SALV compared to female MN. Overall, female SALV speakers have a longer laryngeal cavity geometry than their American counterparts.

Table 5.5

F4 Measurements for Female SALV and Female MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F4 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	3984	4151	4129	3716	3858	3908	3710	3260	3526	3889	3971
SALV2F	4202	4221	4117	3583	3860	3722	3635	4037	3899	4258	3482
SALV3F	3973	3850	3776	3531	3526	3399	3653	3614	3596	3916	3298
SALV4F	3473	3284	3585	3024	3220	3239	3271	3459	3520	3168	3154
SALV5F	4105	4112	4003	3831	3489	3691	3527	3997	3777	4342	3466
SALV6F	4130	4150	4138	3960	3951	3743	3584	3839	3761	4220	3400
SALV7F	4166	4094	4163	3528	3776	3602	3625	3848	3764	4168	3458
SALV8F	3706	3613	3594	3647	4270	3577	3422	3778	3532	3759	3232
SALV9F	3689	3823	3672	3719	3649	3575	3562	3792	3842	3734	3512
SALV10F	3776	3672	3607	3527	3687	3474	3599	3686	3978	3545	3584
SALV11F	4117	4021	4158	4139	3918	3612	3715	3643	3754	4176	3428
SALV12F	4588	4453	4377	3967	4212	4002	3996	4446	4090	4480	3794
SALV13F	3674	4216	4239	4156	4356	3956	3873	3960	3922	4365	3699
SALV14F	3928	3674	3916	3351	2985	3542	3663	3785	4019	4258	3726
SALV15F	4053	4018	4056	3906	3963	3496	3576	3968	3819	4125	3399
Mean	**3971**	**3957**	**3969**	**3706**	**3781**	**3636**	**3627**	**3807**	**3787**	**4027**	**3507**
St. Deviation	276.4	301.2	259.8	302.7	375.4	208.7	169.4	273.9	181.3	355.9	218.2
MN Female	**3766**	**3414**	**3230**	**3288**	**3447**	**3481**	**3490**	**3757**	**3837**	**3515**	**3802**

The female SALV average measurement for F4 is 3797 Hz. The MN average for F4 is 3548 Hz, which is only 249 Hz less than SALV speakers. There are no noticeable acoustic differences for F4 between female SALV and female MN speakers. The averages for all the vowels are below the JND of 600 Hz.

F4 for Male SALV. No major differences exist in F4 between SALV males and MN males. Table 5.6 shows F4 measurements for male SALV compared to male MN speakers.

Table 5.6

F4 Measurements for Male SALV and Male MN Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
F4 Correlate	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	3798	3736	3626	3569	3602	3613	3485	3715	2667	3694	3105
SALV2M	3489	3511	3507	3418	3588	3476	3435	3662	3512	3565	3472
SALV3M	3888	3719	3720	3910	3798	3607	3908	3867	3739	4042	3611
SALV4M	3595	3514	3329	3139	3325	3379	3331	3378	3651	3286	3296
SALV5M	3861	3354	3502	3247	3766	3706	3717	3567	3969	3965	3901
SALV6M	3499	3421	3549	3522	3435	3494	3648	3794	3589	3391	3095
SALV7M	3639	3921	3609	3625	3858	3882	3531	3737	3750	4042	4031
SALV8M	4281	4217	4385	3886	4418	3478	3397	4056	3984	4233	3483
SALV9M	3477	3575	3565	3271	3669	3425	3511	3649	352	3726	3606
SALV10M	3888	3698	3743	3537	3742	3968	3403	3886	3881	3844	3815
Mean	**3742**	**3667**	**3654**	**3512**	**3720**	**3603**	**3537**	**3731**	**3309**	**3779**	**3542**
St. Deviation	253.0	256.1	282.6	256.3	295.5	196.4	175.2	187.2	1105.1	304.2	318.2
MN Male	**3665**	**3687**	**3640**	**3600**	**3722**	**3608**	**3697**	**3641**	**3662**	**3677**	**3427**

The male SALV average measurement for F4 is 3617 Hz. Their MN counterparts' average is 3638 Hz. The acoustic difference is only 21 Hz, well below the JND threshold of 600 Hz (Appendix A). Based on this data, SALV males have a slightly shorter pharyngeal cavity geometry than MM males.

Appendix E: Intensity in Running Speech for Salvadoran Speakers

Intensity in Running Speech for Salvadoran Speakers

Intensity is measured in decibels (dB); ithelps to determine how quiet or loud a speech sequence is perceived (Koffi, 2019, p. 42). Although intensity is not used as a distinctive feature in languages, it will facilitate the characterization of SALV participants. For two sounds to be perceived as different, they must have a JND ≥ 3 dB (Appendix A). The GAE data collected by Koffi and Krause (2020) for intensity of female (p. 76) and male participants (p. 85) will be used here.

Intensity for Female SALV. Table 5.7 shows intensity measurements for female SALV compared to female GAE speakers. In running speech, female SALV English would be perceived as louder than GAE.

Table 5.7

Intensity Measurements for Female SALV and Female GAE Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
Intensity	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	72	75	71	76	71	72	72	72	74	73	71
SALV2F	70	70	71	73	74	75	71	73	72	110	68
SALV3F	71	74	73	74	77	74	77	70	66	70	75
SALV4F	73	75	74	74	78	76	78	74	75	77	72
SALV5F	77	78	59	77	76	77	74	75	77	67	71
SALV6F	70	75	70	74	73	70	73	75	73	67	72
SALV7F	71	72	73	74	75	73	76	75	76	66	74
SALV8F	72	71	68	71	73	79	69	70	73	64	68
SALV9F	73	71	72	74	75	74	75	73	71	72	73
SALV10F	72	75	75	77	75	76	77	73	73	73	72
SALV11F	69	70	71	73	70	72	73	71	69	62	67
SALV12F	75	76	74	77	75	73	73	75	76	66	74
SALV13F	56	74	72	75	74	75	75	76	76	71	74
SALV14F	72	76	71	77	75	76	75	76	76	71	77
SALV15F	75	77	74	75	74	75	74	75	76	70	74
Mean	**71**	**74**	**71**	**75**	**74**	**74**	**74**	**74**	**74**	**72**	**72**
St. Deviation	4.7	2.5	3.8	1.8	2.1	2.3	2.4	2.0	3.1	11.2	2.8
GAE	**55**	**55**	**54**	**58**	**57**	**57**	**54**	**55**	**55**	**56**	**56**

The average intensity for female SALV speakers is 73 dB, while the average for female GAE speakers is 56 dB. With a difference of 17 dB, the intensity of female SALV speakers in running speech is louder than their GAE counterparts. Four of the eleven vowels are unstable (36%), as their standard deviations go beyond the ≥ 3 dB threshold. For the 11 vowels, SALV female vowels would be perceived as louder than female GAE vowels.

Intensity for Male SALV. Male SALV speech can be perceived as louder than GAE in running speech. Table 5.8 shows intensity measurements for male SSE compared to male GAE.

Table 5.8

Intensity Measurements for Male SALV and Male GAE Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
Intensity	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	72	68	72	73	73	74	73	70	75	75	74
SALV2M	76	74	70	74	71	72	75	72	76	77	71
SALV3M	72	76	68	65	72	71	81	70	73	74	70
SALV4M	73	77	74	77	114	77	77	74	75	73	74
SALV5M	67	71	67	71	71	72	69	70	69	61	66
SALV6M	76	79	74	76	77	77	76	71	77	71	76
SALV7M	71	71	74	78	75	75	77	78	71	69	70
SALV8M	67	67	65	72	70	69	69	66	67	61	65
SALV9M	73	72	73	76	74	74	76	76	74	66	70
SALV10M	78	73	71	72	71	72	70	70	74	60	69
Mean	**73**	**73**	**71**	**73**	**77**	**73**	**74**	**72**	**73**	**69**	**71**
St. Deviation	3.6	3.8	3.2	3.8	13.2	2.6	4.0	3.5	3.2	6.3	3.5
GAE	**61**	**61**	**62**	**60**	**60**	**59**	**55**	**57**	**59**	**63**	**63**

The average intensity of male SALV in running speech is 72 dB while their GAE counterparts have an average of 60 dB. The SALV speech is louder by 12 dB and can be qualified as louder than GAE. Almost all SALV intensity measures are unstable (91%) as ten out of eleven vowels go beyond the ≥ 3 dB threshold for their standard deviation. Male SALV speech could be perceived as louder than GAE speech.

Appendix F: Duration in Running Speech for SALV Speakers

Duration in Running Speech for SALV Speakers

The last correlate for our insights in SALV speech is duration. Duration does not plat a relevant role in distinguishing vowels according to Peña (2019). We will contrast duration of SALV participants and MN speakers. The acoustic threshold for perceiving duration differences is a JND of ≥ 10 ms.

Duration for Female SALV Speakers. Table 5.9 shows duration measurements for female SALV compared to female MN.

Table 5.9
Duration Measurements for Female SALV and Female GAE Vowels

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
Duration	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1F	231	86	188	129	190	188	132	189	242	88	178
SALV2F	186	60	135	123	123	93	105	131	131	70	158
SALV3F	115	88	203	95	131	93	132	150	170	83	179
SALV4F	91	79	133	114	91	88	94	112	110	109	110
SALV5F	136	71	147	104	181	153	151	122	104	43	76
SALV6F	131	79	131	95	115	109	188	93	124	66	109
SALV7F	110	85	153	111	128	73	110	115	125	64	132
SALV8F	121	74	127	118	137	93	104	126	117	52	134
SALV9F	187	125	207	190	159	195	124	165	145	204	224
SALV10F	198	100	161	137	195	118	142	211	172	117	181
SALV11F	143	108	141	74	174	118	108	139	164	59	151
SALV12F	145	68	133	122	115	128	127	118	130	71	131
SALV13F	79	59	112	92	80	87	85	85	87	62	79
SALV14F	183	67	139	91	104	87	77	147	139	37	153
SALV15F	182	74	125	96	113	113	91	157	113	63	128
Mean	**149**	**82**	**149**	**113**	**136**	**116**	**118**	**137**	**138**	**79**	**142**
St. Deviation	43.5	18.1	28.8	27.3	36.1	36.7	28.9	33.9	37.6	40.8	39.9
GAE	**156**	**97**	**127**	**82**	**160**	**187**	**116**	**124**	**177**	**138**	**112**

The average duration of female SALV vowels in running speech is 123 ms. Female MN average duration is 11 ms longer at 134 ms. There are two occurrences where there is no noticeable difference (≥ 10 ms, Appendix A) in duration. They are the *thought* vowel [ɔ] and the *fleece* vowel [i]. Nine of the eleven vowels (81%) have a difference of ≥ 10 ms. The highest standard deviation for female SALV vowel duration is the *fleece* [i] sound at 43.5 ms. The lowest deviation is the *kiss* [ɪ] sound at 18.1 ms.

Duration for Male SALV Speakers. The duration of male SALV vowels in running speech is longer when compared to GAE speakers. Table 5.10 shows duration measurements for male SALV speakers compared to male GAE speakers.

Table 5.10

Duration Measurements for Male SALV and Male MN

Vowel Sound	**fleece**	**kiss**	**face**	**dress**	**trap**	**lot**	**thought**	**goat**	**goose**	**comma**	**letter**
Duration	**[i]**	**[ɪ]**	**[e]**	**[ɛ]**	**[æ]**	**[ɑ]**	**[ɔ]**	**[o]**	**[u]**	**[ə]**	**[ɚ]**
SALV1M	135	57	142	110	120	91	97	138	150	59	129
SALV2M	107	70	149	91	156	85	128	139	105	101	190
SALV3M	114	31	102	43	99	55	96	79	87	66	87
SALV4M	119	116	169	116	123	86	129	135	151	102	201
SALV5M	82	49	99	77	116	91	101	97	97	51	166
SALV6M	117	105	153	136	127	99	112	169	169	157	184
SALV7M	111	55	98	86	113	95	122	73	166	56	89
SALV8M	123	79	134	101	104	105	84	133	133	63	177
SALV9M	111	81	98	85	105	74	92	116	121	65	116
SALV10M	113	91	108	109	133	108	101	110	96	105	136
Mean	**113**	**73**	**125**	**95**	**120**	**89**	**106**	**119**	**128**	**83**	**148**
St. Deviation	13.5	26.3	27.1	25.4	16.7	15.5	15.7	29.8	30.6	33.3	41.8
GAE	**165**	**99**	**112**	**100**	**161**	**200**	**112**	**103**	**172**	**105**	**107**

The duration average for male SALV vowels is 108 ms. Their GAE counterparts have a higher duration average of 130 ms, a difference of 22 ms. The highest standard deviation for duration of vowels in SALV speech is the *comma* vowel [ə] with a standard deviation of 41.8 ms. The *fleece* vowel [i] has the lowest standard deviation, at 13.5 ms. Only the *dress* vowel [ɛ] and the *thought* vowel [ɔ] of the two groups of speakers have values ≤ 10 ms. This means that there is a noticeable difference of duration in nine of the eleven vowels (81%).

Summary

Although the data included in this appendix is not used for intelligibility analysis, it offers insights into other features of vowel production that can be used for a comprehensive analysis of Salvadoran-accented English vowels. It completes the picture of the acoustic phonetic characteristics of the vowels produced by the participants.

Female SALV speakers are characterized as having a higher pitch than their MN counterparts. Their most lip rounded vowel is the *fleece* vowel [i]. In running speech, female SALV vowels are perceived to be louder. The SALV female participants have shorter vowel duration than their MN counterparts. For male SALV speech, pitch is higher than male MN speech in all the vowel inventory. The most lip-rounded sounds for male SALV are the *letter* [ɚ] and *dress* [ɛ] vowels, while the most lip-rounded vowel sounds for male MN speech are the *letter* [ɚ] and the *kiss* vowels [ɪ]. In running speech, male SALV vowels are perceived to be louder than GAE vowels. Lastly, SALV male vowels are longer in duration when compared to male MN vowels.

The data in this study offers a complete phonetic inventory for Salvadoran spoken English in running speech. Salvadoran students can also benefit from this study as they can understand which vowels may be more problematic for them. In addition, pronunciation teaching relies heavily on input and feedback of L2 speech. The proposed SALV data can provide specific acceptable ranges of validation exclusive to Salvadoran-accented English.