A Sociophonetic Investigation of Unstressed Vowel Raising in the Spanish of a Rural Mexican Community

DISSERTATION

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By

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Abstract

While the vocalic system in Spanish is typically described as stable, there is increasing evidence for dialectal vowel variation. The focus of the current study is variable vowel raising in rural Michoacán Spanish, which involves the mid vowels, /e/ and /o/, in unstressed post-tonic positions and their variable realizations as [e, i] or [o, u], respectively. For example, the word grande ‘big’ can be pronounced as either [grandɛ] (non-raised) or [grandi] (raised). In this dissertation, I perform a sociophonetic study of this variable process using acoustic information about the formant values of the relevant vowels and I examine the influence of different linguistic and social factors on this phenomenon. Previous studies on unstressed vowel raising mainly focus on Puerto Rico (Holmquist 1998, 2005 and Oliver Rajan 2007, 2008). Several studies mention that vowel raising occurs in Mexico, but none offer a thorough description of the process. My dissertation focuses on the variation in mid vowel realizations found in the Spanish spoken in Colongo, Michoacán, Mexico, and it is the first systematic description of vowel raising in the region.

As for the independent variables, I look at linguistic factors that have been shown to influence raising in other dialects such as the tonic vowel, preceding consonant, following sound, stress pattern, and whether the vowel is in an open or closed syllable, among others. The analysis of these factors allows us to examine the relation between vowel raising and another vocalic process present in Mexican Spanish, namely unstressed...
vowel devoicing (UVD), by which unstressed vowels become devoiced or reduced in their duration. In this dissertation, I propose that both of these processes are cases of vowel weakening and I provide evidence to support this claim. Given this Weakening Hypothesis, I expect vowel raising to occur in the same, weak positions where UVD occurs, namely in closed syllables and utterance-finally, and my results support this idea. As part of the Weakening Hypothesis, I also propose that weakening will lead to an increase in coarticulatory effects, which are more likely in contexts where there is reduction in duration (Browman and Goldstein 1989, 1992). Thus, I expect to see these coarticulatory effects from both preceding and following sounds in addition to effects from the tonic vowel, and my results find this to be true as well.

The social factors of age, education level, occupation, and mobility, since they are highly correlated, are used in an analysis of social networks to look at social differences within the community. I create a numerical index incorporating these factors that ultimately results in the division between an open or closed social network. I expect less vowel raising in the open social network, where participants have more access to interactions outside of Colongo, and more vowel raising in the closed social network, where participants have less outside influence, and my results confirm this hypothesis. The division into social networks helps us to better understand the social differences among the community members and the effect of these differences on vowel production.
Dedication

This dissertation is dedicated to all the members of the Colongo community who graciously offered me their time and allowed themselves to be recorded. I appreciate each of you for taking the time to speak with me and for providing invaluable insights into your ranchito. This dissertation would not have been possible without your generosity.
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Fields of Study

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Chapter 1. Introduction

When explaining the sounds of Spanish, researchers often comment on the stability of the vowel system. For example, Quilis (1981:129) finds vowel stability when analyzing the frequencies of the formants themselves. Morrison and Escudero (2007) find no significant differences in the formant values of vowels produced by speakers from Madrid, Spain and Lima, Peru. Hualde (2005:124) explains that the Spanish vowel system is simple, where dialectal differences occur mainly in the pronunciation of certain consonants rather than in vowels. So, in this sense, the vowel system can be considered relatively stable when compared to the numerous changes that occur to the consonants in Spanish.

However, there is increasing evidence for dialectal vowel variation. Willis (2008) conducts a preliminary study on vowels in the Dominican Republic and suggests that the production of vowels in Spanish is not as uniform as is commonly suggested. In fact, across different dialects we find unstressed vowel devoicing, vowel harmony, hiatus resolution, where the vowel quality is changed, changes in vowel production due to contact with another language, and unstressed vowel raising, as I discuss in detail in chapter 2. The focus of the current study is variable vowel raising in rural Michoacán Spanish, which involves the mid vowels, /e/ and /o/, in the unstressed post-tonic positions
and their variable realizations as [e, i] or [o, u], respectively. For example, the word *grande* ‘big’ can be pronounced as either [grandə] (non-raised) or [grandi] (raised). In this dissertation, I perform a sociophonetic study of this variable process using acoustic information about the formant values for the vowels of relevance and I examine the influence of different linguistic and social factors on this phenomenon in rural Michoacán.

Previous studies on unstressed vowel raising have primarily focused on Puerto Rico and northwestern Spain. Holmquist (1998, 2005) and Oliver Rajan (2007, 2008) contribute to the study of dialectal vowel variation with their detailed descriptions of unstressed vowel raising in Puerto Rican Spanish. They both explore the factors that contribute to the raising of unstressed post-tonic mid vowels in the western region of the island. Earlier studies of Puerto Rican vowel raising (Navarro Tomás 1948) put forth the idea that high tonic vowels and preceding palatal consonants were the linguistic environments that favored mid vowel raising. However, more recent studies have found additional linguistic and social factors, such as the type of stress and grammatical category of the word, as well as occupation, mobility, and education of the speaker, among others, to be significant in conditioning the variable raising. As for vowel raising in northwestern Spain, Holmquist (1985) finds a correlation between unstressed mid vowel raising and several social factors including involvement in the farming community, gender, and age. While he does not specifically look at linguistic factors in this study, he does suggest that /o/ raising occurs more frequently than /e/ raising, and there may be an effect of the tonic vowel.
A similar type of unstressed mid vowel raising occurs in rural Michoacán, Mexico. However, in contrast to the varieties in Puerto Rico and northwestern Spain mentioned previously, there is a noticeable lack of studies about vowel raising in Mexico. In contrast to the more thorough research on the factors that contribute to vowel raising in those areas, this feature is usually only mentioned when describing certain dialectal regions in Mexico. For example, Boyd-Bowman (1960) offers a descriptive analysis of vowel raising in the states of Guanajuato and Michoacán. Cárdenas (1967) also provides a similar description of final vowel raising in the neighboring state of Jalisco. Both Boyd-Bowman and Cárdenas suggest that a preceding palatal consonant is an environment that favors raising of the mid vowels. Moreno de Alba (1994) presents data from the Atlas lingüístico de México ‘Linguistic Atlas of Mexico’ and shows that mid vowel closure, i.e. raising, happens frequently in several states, including Michoacán. Finally, Parodi and Santa Ana (1997) describe the closing of mid vowels as one of several regional features for Michoacán. The only study that I found that specifically discusses mid vowel raising in Michoacán (Lope Blanch 1979), argues that the closure occurs more frequently after a palatal consonant and also before a pause. Thus, there are several studies that mention that vowel raising occurs in Mexico, but none of them offer a detailed description. Lope Blanch (1979) presents a starting point, but lacks important information about data collection and analysis.

My dissertation research focuses on the social and linguistic factors that influence the variation in vowel realizations found in the Spanish spoken in Colongo, Michoacán, Mexico. This small, rural community offers a unique opportunity to study social
differences because although it may seem like a homogenous group, there are differences in pronunciation based on membership in different social networks within Colongo. This community is additionally unique because there is considerable migration to and from the United States, which leads to exposure to English and other dialects of Spanish. Thus, the concept of mobility, time in and out of Colongo, is included in the current analysis. I consider both acoustic data and the importance of social factors, which is a common methodological practice in sociophonetics, a rapidly growing area in the field of linguistics. Thus, in addition to determining the linguistic contexts that condition vowel raising, I also provide a description of the behavior of social groups within the community in relation to this process. While vowel raising has been cited in dialectal descriptions of Mexico, this is the first systematic description, using acoustic information and including a range of conditioning factors, both linguistic and social, and analysis of its occurrence.

The data for my dissertation comes from recordings with native speakers that I collected while in Mexico in the summer of 2011. I recorded sociolinguistic interviews with 32 participants, 13 years old and older, who were born and raised in and around Colongo. The interviews lasted approximately 30 minutes and covered a variety of topics ranging from school to community celebrations in an effort to find a topic that the participants were excited to elaborate on. The context where raising can occur, post-tonic unstressed mid vowels, is very frequent in everyday usage of the language, therefore there was more focus on finding the topic that elicited the most speech from the speaker rather than trying to guide the speaker to use specific words.
For the data analysis, each post-tonic unstressed mid vowel token was categorically judged as raised or non-raised, and measured acoustically, using the first two formants. Ultimately, I decided not to use the auditory judgments and instead made the raised or non-raised distinction using the Discriminant Analysis of Principle Components (DAPC; Jombart 2008, Jombart, Devillard and Balloux 2010) which is based on the first two formant measurements (see section 4.1.1). Acoustic analysis for each token is a new methodological approach to vowel raising, since most previous studies, with the exception of Barnes (2013), rely solely on auditory judgments, and this method provides a much more precise indication of the changes that the vowels undergo. Thus, I have both categorical and continuous dependent variables which consist of the raised or non-raised distinction and the measurements of the frequencies of the first two formants. Based on the results from previous studies of vowel raising in other dialects and the distinct formant values between the mid vowels, I analyze /e/ and /o/ separately.

As for the independent variables, I include both linguistic and social factors. Using the results from previous vowel raising studies as a model, I look at linguistic factors that could influence raising such as the tonic vowel, preceding consonant, stress pattern, and lexical category of the word. Also, guided by more recent findings I examine whether the vowel is in an open or closed syllable, and whether there is influence of the following sound (Oliver Rajan 2008 and Barnes 2013, respectively). See section 3.4.2.1 for an exhaustive list and detailed description of each of the linguistic factors included in this study. Mexican Spanish is a dialect that is characterized by another vocalic process, namely unstressed vowel devoicing (UVD), by which unstressed vowels become
devoiced or reduced in their duration (Perissinotto 1975, Lope Blanch 1963, among
others). In this dissertation, I hypothesize that both of these processes, i.e. vowel raising
and UVD, are cases of vowel weakening (see section 2.4), and I provide evidence to
support this claim. Given this Weakening Hypothesis, I expect vowel raising to occur in
the same, weak positions where UVD occurs, namely in closed syllables and utterance-
finally. Previous literature on vowel weakening (Flemming 2004) suggests that in
unstressed positions there is a shortened duration, which leads to a reduction in vocalic
contrasts. This is similar to what we find in Colongo, where the mid vowels are variably
raised. As part of the Weakening Hypothesis, I also propose that this weakening will lead
to an increase in coarticulation since coarticulatory effects are more likely in contexts
where there is reduction in duration (Browman and Goldstein 1989, 1992). Kühnert and
Nolan describe coarticulation as, “...the fact that a phonological segment is not realized
identically in all environments, but often apparently varies to become more like an
adjacent or nearby segment” (1999:7). Thus, I would expect to see these coarticulatory
effects from both preceding and following sounds in addition to the tonic vowel, which
would confirm the results from Puerto Rican and Peninsular Spanish vowel raising that
find more raising after a palatal consonant or a tonic high vowel.

Social factors such as age, gender, education level, occupation, and mobility were
also included in this study. However, due the small, rural nature of this community, many
of these factors are correlated, making it nearly impossible to make any conclusions
based on the typically used large-scale social variables, such as education, socioeconomic
status, etc. For example, most of the younger generation has more education than the
older generation, and the majority of the participants who have spent time outside of the community are males, thus making it difficult to tease these factors apart. As a way to incorporate these highly correlated social factors and determine their association with vowel raising, I use an analysis of social networks, which is a commonly used method in the field of sociolinguistics for looking at social differences within communities that are not clearly divided into classes (see section 2.5). I create a numerical index incorporating age, education, occupation and mobility that ultimately resulted in the division between an open or closed social network, where members of the open social network have more access to interactions outside of Colongo and members of the closed social network have less outside influence (see section 3.4.2.2.1). The division into social networks helps to provide us with a better understanding of the social differences among the community members and the effect of these differences on vowel production.

In order to determine the importance of the independent variables on vowel raising, I use mixed effects models in R (R Development Core Team 2011). These statistical models incorporate speaker as a random variable to account for differences based on the individual speakers (see section 4.2). I complement the use of mixed effects models with variable selection using random forests and conditional inference trees to view interactions among factors, both from the party package in R (Hothorn et al. 2013). After having discussed the motivation for the current study, the variables under investigation, and how they are analyzed, I present my overarching research questions and goals in the following section.
1.1 Research questions and goals

The current study addresses the following research questions:

- How can we characterize vowel raising in Michoacán Spanish? How does it compare to other dialects that have this vocalic process, such as those in Spain and Puerto Rico, discussed in previous studies?
- What are the linguistic and social factors that favor raising in this dialect?
- How can social networks be used to divide a seemingly homogenous community into social groups that vary in their use of vowel raising?
- How can unstressed vowel raising be phonologically analyzed? Can our results support the Weakening Hypothesis by showing the similarities between vowel raising and unstressed vowel devoicing in this dialect?

This dissertation contributes to the literature on unstressed vowel raising by focusing on an understudied variety of Spanish. Additionally, this will be one of the first variationist studies on this type of dialectal vowel variation that is based on evidence from acoustic data. Taking the variable nature of vowel raising into account, I aim to advance phonological theory on vowel weakening processes by presenting evidence for the Weakening Hypothesis. I also provide a systematic description of a vowel raising process that differs from other dialects, with more raising of /e/ than /o/ and at a higher rate than has been found previously for other regions. Moreover, my research contributes to dialectological, phonological, phonetic, and variationist literature about Latin
American Spanish, with a focus on Mexican Spanish, and more specifically, Mexican vowels. My study of linguistic variation within this dialect of Spanish suggests a connection between variation of phonetic realizations and social meaning, and I hypothesize that vowel raising is part of the Colongo identity. In my dissertation, I aim to find the connection between sociolinguistics and the phonology and phonetics interface by combining linguistic theory with acoustic results.

This dissertation is divided into six chapters. Chapter 2 presents a review of previous literature on processes involving Spanish vowels, including vowel raising, as well as theories of vowel weakening, and an overview of social networks. Chapter 3 provides the methodology used for my study, including detailed descriptions of the variables, participants, tasks, and data analysis. The results are presented in chapter 4 and the discussion and interpretation of these results in chapter 5. Finally, chapter 6 offers a summary and conclusions from my study as well as contributions and proposals for future research.
Chapter 2: Spanish vowels and vocalic processes, vowel weakening theories, and social networks

This chapter presents a thorough review of the literature on the main topics that are necessary to understand the variation in vowel raising that occurs in Colongo, Michoacán, Mexico. These topics include the behavior of vowels in Spanish, vowel weakening and approaches to the phenomenon, and finally, social networks and their application to the study of linguistic variation. The chapter begins with an introduction to the vowel system in Spanish in section 2.1, with both articulatory and acoustic descriptions. This is followed in section 2.2 by a discussion of several acoustic studies that demonstrate why most researchers describe the Spanish vowel system as relatively stable. Next, section 2.3 examines several processes involving vowels that alter the typical Spanish vocalic system, including unstressed vowel devoicing, vowel harmony, hiatus resolution, vowel variation due to language contact, and unstressed vowel raising. Each of these vowel processes is then divided by dialect. The main focus of the vowel processes in this chapter is on the examples of unstressed vowel raising, since that is the topic of study of this dissertation. The few studies of vowel raising in Mexico that are available are presented in the final subdivision of section 2.3. In the following section, 2.4, I discuss several vowel weakening theories that have been instrumental in the
development of my own analysis of vowel raising as a type of vowel weakening process, and I then elaborate on my Weakening Hypothesis. Then, in section 2.5, I examine how social networks have been used within the field of sociolinguistics and how the formation of social networks can be adapted to fit the community under study. These studies provide the background necessary to understand the reasoning behind the creation of the social networks based on social factors other than social ties in Colongo. In the final section of the chapter I summarize the factors and findings for vowel raising that are most relevant for the current project.

2.1 The vowel system in Spanish

Spanish has a five vowel system where each vowel is typically described in terms of the articulatory characteristics of tongue height and the horizontal position of the tongue (Gil Fernández 1990). For the height dimension, Spanish uses three categories which are low, mid and high. For the horizontal dimension, Spanish also differentiates three categories which are front, central and back. A third dimension that is sometimes mentioned is lip roundness, according to which a vowel can be characterized as rounded or non-rounded. In Spanish, this dimension is non-contrastive because the back vowels are the only vowels that are rounded. Based on these descriptions, the vowels form the shape of a triangle when they are arranged in a table based on their articulation. This can be seen in table 1 below (based on the figure from Hualde 2005:121). Thus, /i/ is a high, front vowel, /e/ is a mid, front vowel, /a/ is a low, central vowel, /o/ is a mid, back vowel
and /u/ is a high, back vowel. The back vowels /o/ and /u/ are rounded and the front vowels and central vowel are non-rounded.

<table>
<thead>
<tr>
<th></th>
<th>Front</th>
<th>Central</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>i</td>
<td></td>
<td>u</td>
</tr>
<tr>
<td>Mid</td>
<td>e</td>
<td>o</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>a</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Spanish vowel phonemes

Acoustically, the five vowels of Spanish are usually identified through the frequency values of their first two formants, F1 and F2. F1 is directly correlated with the opening of the oral cavity, so the greater the opening the higher the frequency of F1 (Gil Fernández 1990). In other words, the lower the vowel, the higher the F1 value is. So /a/, being the most open (or low) vowel, has the highest F1 value and the more closed (high) vowels /i/ and /u/ have the lowest F1 values. The mid vowels /e/ and /o/ have F1 values in the middle range. F2 is related to the horizontal position of the tongue, so the closer to the front, the higher the frequency of F2, and the closer to the back, the lower the frequency of F2. As a result, /i/ has the highest F2 value and /u/ has the lowest F2 value. The rounding of the lips also correlates with a lowering of F2, so the more rounded the lips, the lower the value of F2. Although the frequency of the formants for each vowel will vary among speakers, there will still be a clear pattern of five distinct vowels, especially when we consider the distance between F1 and F2. Females tend to have higher formant
values than men (Martínez Celdrán 1998). Despite these gender-based differences in formant values, many authors provide the average or a range of formant values for F1 and F2 for each of the vowels that other researchers can use for comparison. I will discuss this range of formant values for the first two formants further in the following section.

2.2 Acoustic studies on Spanish vowel production

In this section I discuss several studies that offer general descriptions of the Spanish vowels based on acoustic data. Their results serve as a starting point for the investigation of dialectal differences in vowel production.

Quilis and Esgueva (1983) conducted an acoustic study on the Spanish vowels in order to examine their acoustic characteristics and note any differences between stressed and unstressed vowels. They designed their stimuli to capture what they consider the “normal” position of the vowel, which is in between bilabial consonants so that the articulation of the vowel is not affected by the surrounding consonants. Some examples of the words used to elicit “normal” placement of the vowels are: pipa, Pepa, pipero, pepona, mama, mamita, viva, vivero. Through the use of these carefully selected words they were able to measure each of the vowels in stressed and unstressed positions. Quilis and Esgueva recorded 16 men and 6 women reading 30 different words within carrier phrases at a normal pace and in a natural manner. The participants were university students from both Spain and Latin America. The authors looked at the first three
formants\(^1\) (F1, F2, F3) and the length of the vowels. For each informant they plotted the formant values and the duration of each vowel. On a separate chart they kept track of the average formant frequencies for stressed vowels, unstressed vowels, and the average for all vowel values (stressed and unstressed combined). They also included a summary formant chart with the average formant values for all the speakers. Based on their data, Quilis and Esgueva conclude that on average stressed vowels have a longer duration than unstressed vowels. They found a small difference in vowel duration between Latin Americans and Spaniards, where Latin Americans tend to have longer stressed vowels, but shorter unstressed vowels than the Spaniards (1983:243). Stressed and unstressed vowels for women tend to be longer than men’s vowels, and women have a larger vowel space. They did not find a great difference in formant frequencies for stressed and unstressed vowels, which is relevant for the current study. While they mention the difference in vowel duration between the Latin American and Spanish informants, there is no discussion of differences or similarities in formant frequencies. They do, however, provide the average formant values expressed in hertz for the stressed and unstressed vowels of all the male speakers combined, which I have summarized in table 2. Since there was quite a bit of fluctuation in F3 values even within an individual speaker, and sometimes the third formant did not appear, those values are not included in the summary. This chart gives us an idea of the formant values that they found for male

\(^1\) Not all of the vowels analyzed showed a third formant, especially /o, u/. They did not find steady values for F3 and it is not clear what they were looking to find with this measurement.
speakers from a variety of dialects, including Mexico, Ecuador, Chile, and several areas of Spain, although no specific dialectal comparisons can be made. As expected, they find that mid vowels have higher F1 values than high vowels, and the difference is approximately 200Hz. We can use the resulting pattern of formant frequencies as a basis for comparison with our own formant values of unstressed vowels.

<table>
<thead>
<tr>
<th>Vowel</th>
<th>F1 (s.d.)</th>
<th>F2 (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/i/</td>
<td>264.5 (37.8)</td>
<td>2317.5 (154.3)</td>
</tr>
<tr>
<td>/e/</td>
<td>453.8 (60.8)</td>
<td>1995.0 (113.2)</td>
</tr>
<tr>
<td>/a/</td>
<td>657.28 (38.4)</td>
<td>1215 (87.5)</td>
</tr>
<tr>
<td>/o/</td>
<td>474.5 (52)</td>
<td>888.4 (103)</td>
</tr>
<tr>
<td>/u/</td>
<td>293.5 (37.7)</td>
<td>669.08 (44.2)</td>
</tr>
</tbody>
</table>

Table 2: Average mean formant values (Hz) for Spanish vowels with standard deviations (adapted from Quilis and Esgueva 1983)

Bradlow (1995) performed an acoustic analysis comparing vowels in English and Spanish. Her informants were four male General American English speakers from New York and four male speakers of Madrid Spanish. The Spanish speakers pronounced each of the following words: bita, beta, bata, bota, puta, in the carrier sentence, Escribe ____ bien ‘Write _____ well’. Each sentence was read five times in random order, resulting in 20 tokens for each tonic vowel. I present these results in table 3 below (adapted from Bradlow 1995:1918). Bradlow determined that although the two languages have four similar vowel categories in common (/i/, /e/, /o/, /u/), the actual production of these vowels differs by language specific differences in articulation. That is to say, even though some of the vowels have the same phonological feature specifications in the two
languages, their precise location in the acoustic space is not the same for both languages. More specifically, she found that English vowels are articulated with a more fronted tongue position, based on higher F2 values than Spanish vowels. The most relevant results for the current study are the mean values for the first two formants of each of the five Spanish vowels. The mid vowels can be differentiated from the high vowels through the measurement of the first two formants. The formant information is similar to what was presented in Quilis and Esgueva (1983), but this data is only from Madrid Spanish speakers, so that needs to be kept in mind before making any direct comparisons.

<table>
<thead>
<tr>
<th>Vowel</th>
<th>F1 (s.d.)</th>
<th>F2 (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/i/</td>
<td>286(6)</td>
<td>2147(131)</td>
</tr>
<tr>
<td>/e/</td>
<td>458(42)</td>
<td>1814(131)</td>
</tr>
<tr>
<td>/a/</td>
<td>638(36)</td>
<td>1353(84)</td>
</tr>
<tr>
<td>/o/</td>
<td>460(19)</td>
<td>1019(99)</td>
</tr>
<tr>
<td>/u/</td>
<td>322(20)</td>
<td>992(121)</td>
</tr>
</tbody>
</table>

Table 3: Average mean formant values for Spanish vowels with standard deviations (adapted from Bradlow 1995)

Martínez Celdrán and Fernández Planas (2007) discuss an acoustic analysis that was previously performed by Martínez Celdrán (1995). In that study, ten university students (speakers of standard Spanish, which I believe in this case means from Spain), five males and five females, were recorded pronouncing a series of six nonsense words five times each for each vowel. This resulted in a total of 300 tokens per vowel. The vowel was always in a stressed position and the variation was in the stop that preceded the vowel, which was either voiced or voiceless. The following are a few examples of
how the nonsense words were constructed: *pam-p/b-V-na, tan-t/d-V-na, kan-k/g-V-na*, e.g. *pampana, tandina*, etc., (Martínez Celadrán and Fernández Planas, 2007:174). The results show that women tend to have a larger vowel space than men, based on the average values of the formant frequencies, which coincides with what Quilis and Esgueva (1983) found. Martínez Celadrán and Fernández Planas also discuss differences between stressed and unstressed vowels. Based on a previous study (Martínez Celadrán 1984), they show a formant chart with both stressed and unstressed vowels plotted. The figure shows that there is a small difference between the two, and unstressed vowels tend to be more centralized than their stressed counterparts. They claim that this pattern emerges in experimental laboratory situations and that in quick and less careful speech the unstressed vowels may be even more centralized (2007:188). However, statistical tests show the difference between the stressed and unstressed vowels to be insignificant. This is similar to what Quilis and Esgueva (1983) conclude about the lack of differences in formant frequencies for stressed and unstressed vowels, although no statistical tests were performed.

In a more thorough investigation, Morrison and Escudero (2007) performed a cross-dialectal comparison of vowels in sentence final position through an acoustic study of monolingual Spanish speakers from Madrid, Spain and Lima, Peru. They had 20 speakers from each region, ten males and ten females, who were university students. The participants read randomized lists of sentences which had the structure “En CVCe y CVCo tenemos V” (2007:1505). The vowel remained the same within the sentence and the consonant varied throughout the sentences. This resulted in each vowel phoneme
being produced 12 times. The authors performed a series of ANOVAs and determined that the fundamental frequency and duration of the vowels were significantly different between the group of Peruvian speakers and the group of Peninsular speakers. The Peruvian speakers had longer vowel duration and higher fundamental frequency in their vowels than the Peninsular speakers. However, when comparing the whole vowel system, the authors did not find a significant difference in formant values between the two dialects, nor were there gender differences based on dialect.

Several of the studies discussed in this section give us an overview of the range of formant values for the first two formants that are typically associated with Spanish vowels. While some studies, such as Quilis and Esgueva (1983), did not investigate dialectal differences, others, for example Morrison and Escudero (2007), did consider dialect as a variable, but did not find it to be significant. It is this possibility of dialectal differences in Spanish vowel production that will be explored in the following section.

2.3 Variation in Spanish vowel production

The studies mentioned in section 2.2 support the typically referred to idea of the stability of the vowel system in at least some dialects of Spanish. For the current study, however, I am more interested in dialects that do not demonstrate the same degree of stability. As such, I will now move on to discuss several phenomena involving vowel production that result in variation from the usual system in various varieties of Spanish.

Within the literature that analyzes vowels, researchers argue that there may be differences in vowel production based on the method used to elicit those vowels. For
example, Martínez Celdrán and Fernández Planas (2007) suggest a difference in vowel production in laboratory settings when compared to casual speech. They found that unstressed vowels have the tendency to be more centralized in less careful speech. Willis (2008) presents an illustrative example of vowel variation in the Dominican Republic and he also suggests that there may be a difference between vowels that are read out of context and those that are part of spontaneous speech. He points out that many previous acoustic studies analyzed the vowels in words in isolation or in carrier sentences whereas variationist studies used more spontaneous speech such as news broadcasts, where there was a more impressionistic auditory analysis, typically without acoustic measurements.

In this introductory study, the author presents vowel variation that stems from vowel category overlap, where two different vowels are produced in the same vocalic space, within and across individual speakers. In other words, there are cases where one speaker produces an unstressed /a/ in the same vowel space where an unstressed /e/ and even tonic /e/ are also produced, suggesting that the distinctions between vowels are not as clear-cut as previous literature has suggested.

Both Martínez Celdrán and Fernández Planas (2007) and Willis (2008) contribute to the literature on dialectal vowel variation by showing that the types of methods used, such as reading or spontaneous speech, can have an effect on the results and should be considered when comparing formant values. I will now discuss the following types of variation in vowel production: unstressed vowel devoicing, vowel harmony, hiatus resolution, variation due to language contact, and unstressed vowel raising.
2.3.1 Unstressed vowel devoicing

Unstressed vowel devoicing (UVD) is used to describe a range of changes to unstressed vowels, from reduction of duration and devoicing to complete loss of the vowel. Following Delforge (2008a), I use the term unstressed vowel devoicing (UVD) although other authors refer to it as unstressed vowel reduction (UVR), and both terms refer to the range of changes mentioned above. Note that the vowel quality is not changed in this process, so UVD is a different phenomenon than the current topic of investigation, unstressed mid vowel raising. UVD is typically associated with both Mexican and Andean Spanish. Furthermore, since this distinct process is prevalent in Mexican Spanish it needs to be considered in the analysis of my own data, alongside unstressed mid vowel raising.

2.3.1.1 Unstressed vowel devoicing in Mexico

Perissinotto (1975:26) says that the weakening or loss of unstressed vowels may be the most notable characteristic of Mexican Spanish in the capital. Boyd-Bowman (1952) found vowel devoicing and vowel loss in people from all social levels in the area around Mexico City. This nearly always occurred in contact with /s/, especially between /s/ and a voiceless consonant or /s/ in word-final position. One example that he provides is *trescient's* 'three hundred' (1952:138), where the final /o/ has been reduced in duration or deleted. Vowel loss could occur with any vowel although he found /a/ to be the most resistant. In Guanajuato, Boyd-Bowman attributed this vowel reduction or loss to the
“quick and nervous speech of the miners” (1952:138). Canellada de Zamora and Zamora Vicente (1960) point out that vowel reduction to the point of elision in Mexican Spanish is especially noticeable to speakers of other dialects of Spanish. The authors conducted a study near the capital, through the use of spontaneous data that they observed in various public places, like taxis, churches, stores, universities, etc., to see if they could make any further observations about its occurrence. They claim that vowel loss happened in all social classes and that people were not necessarily aware of it, since it happened in all types of social situations, such as lectures or university conferences. The most common place for vowel loss was in “absolute syllable initial position,” initial syllables with no onset, before an /s/. One example of this is spérate ‘wait’ (1960:226). Vowels were lost in other positions as well, pre- and post-tonic, especially when next to /s/. Their most noticeable finding was that stressed vowel devoicing also occurs, although not as frequently as vowel devoicing in unstressed syllables. This is especially common with stressed /i/, which is the most likely stressed vowel to be lost in contact with /s/. One example of this is mamas ‘t’ ‘gorgeous’ (Canellada de Zamora and Zamora Vicente 1960:236). Lope Blanch (1963) considers the two previous studies more comprehensive than other studies on Mexican vowels because they do include a systematic analysis specifically of UVD. However, he notes that Boyd-Bowman’s (1952) study was impressionistic and not extensive enough, and that Canellada de Zamora and Zamora Vicente’s (1960) study included too many extreme cases that do not reflect the reality. Thus, in his study Lope Blanch captured the spontaneous speech of 100 people, from various social classes that are representative of Mexico City, including conversations
with informants, between informants, etc. and only some of them were recorded. Like the researchers before him, Lope Blanch claims that vowel weakening/loss can occur in all social classes and that there is no social systematization of the process. He found devoicing/loss is most common next to voiceless consonants, especially /s/, such as dient(ə)s ‘teeth’, ant-s ‘before’, and much(ə)s ‘many’ (1963:9), which favored weakening/loss 90% of the time. He did not find any cases of tonic vowel loss and only a few cases of tonic vowel devoicing. The findings of the previously mentioned studies, namely UVD in closed syllables, will need to be considered for the current study since that is a position where vowel raising tends to occur as well. This suggests that perhaps these two distinct processes should be considered as different types of vowel weakening, an idea that is examined in our Weakening Hypothesis in section 2.4.

2.3.1.2 Unstressed vowel devoicing in Andean Spanish

In addition to its occurrence in Mexican Spanish, unstressed vowel devoicing has also been found in several varieties of Andean Spanish, including those of Ecuador, Bolivia, and Peru. Further literature on these findings can be found in Gordon (1980), Hundley (1983), Lipski (1990), Delforge (2008a, 2008b), and Sessarego (2012), among others. I will first discuss the findings for Ecuador and then move on to Peru.

2.3.1.2.1 Unstressed vowel devoicing in Ecuador

Lipski (1990) examines unstressed vowel devoicing (UVD) in Ecuadorian Spanish and finds that it usually occurs with the front vowels /e, i/ in contact with /s/.
This is based on a corpus of taped interviews with 20 middle class participants of a wide age range from various areas in Ecuador. Some of his examples of UVD are *usted(e)s* ‘you (plural)’ and *oyent(e)s* ‘listeners’ (1990:3). He concludes that UVD occurs in the weakest prosodic segments. Thus, UVD is more prevalent in post-tonic word-final position than in pre-tonic position. Lipski also finds that UVD tends to occur more frequently in closed syllables, typically next to a voiceless consonant, than in open syllables. Furthermore, intervocalic /s/ voicing, which occurs frequently in Ecuadorian Spanish, does not tend to occur as often when adjacent to a devoiced vowel. In order to explain the higher degree of devoicing of front vowels, as opposed to other vowels, when next to /s/, Lipski uses an articulator based model of feature geometry and argues that front vowels and /s/ share articulatory characteristics and points towards theories that suggest that both have the feature [+coronal]. According to his analysis, there is more interaction between /s/ and the front vowels, as opposed to non-front vowels, because they share the [+coronal] feature. He proposes that vowel devoicing is reinforced as a result of the interaction with /s/, rather than being caused by it. Once devoicing and a shortened duration have occurred, the front vowels become less vowel-like, that is to say less [-consonantal], and then have even more similar features to /s/. In the case of elision, the Place node that was once associated with the vowel gets re-associated with the /s/.

The findings presented in this study are especially relevant for rural Michoacán Spanish, which is also recognized as a variety with frequent UVD.
2.3.1.2.2 Unstressed vowel devoicing in Peru

Delforge (2008a, 2008b) looks at the process of unstressed vowel devoicing (UVD) in Andean Spanish. Her studies focus on the Spanish of Cuzco, Peru and use acoustic analysis and the framework of Articulatory Phonology to show and explain the gradient effects and variable occurrence of UVD, which had been shown by previous studies to involve /o/ or /e/, especially near /s/ and in word-final syllables. Delforge’s (2008a) experiment involved the analysis of a ten minute section of an interview for each of her 16 participants. High frequency words (such as pues ‘well’ or después ‘after’) were excluded and only the first three utterances of any word were counted. Her initial spectrographic analysis showed that 9.9% of unstressed vowels were reduced or devoiced. She then divided the reduced vowels into four categories according to their degree of reduction, based on their acoustic characteristics: partially devoiced/shortened, weakly voiced, completely devoiced, or apparently elided. She further analyzed any possible changes in the vowel quality of the reduced sounds since there is some debate as to whether UVD results in changes in vowel quality. Comparisons of the distance between F1 and F2 for reduced, unreduced and stressed vowels supported the idea that centralization is not occurring and that it really is just devoicing or shortening since there were no significant differences among the formants for reduced and unreduced vowels. Therefore, Delforge opts for the description unstressed vowel devoicing (UVD) instead of the traditionally used unstressed vowel reduction (UVR), since according to her results...
the process involves changes in voicing and duration but not in vocalic quality. For this reason I have also adopted the use of UVD throughout this dissertation.

When studying all of the target vowels together, Delforge found that mid vowels were most likely to be devoiced, when considered as a percentage of the devoiced tokens. More precisely, /e/ tokens made up 37% of the devoiced tokens and /o/ made up 26%. However, since these two vowels have a high frequency of occurrence, a devoicing rate measurement is a better method to compare all of the vowels. The devoicing rate is calculated by taking the number of times a particular vowel is devoiced divided by the number of unstressed vowel tokens of that same vowel. The devoicing rate showed the most devoicing for /e/, 20% of the time, followed by /o/ and /i/, which were both devoiced 13% of the time. Although previous research suggested that /e/ was the most likely vowel to undergo devoicing in the word-final position, that was not the case here. The author found that in sandhi syllables, where the following consonant belongs to a different word (i.e. traje típico ‘typical suit’), the high vowels and /e/ are the most likely to be devoiced, which is the same as for word-medial position. The other word-final positions, either closed by /s/ or before a pause, do have high rates of devoicing for all the vowels. Another factor that is likely to lead to devoicing is the presence of a voiceless consonant either before or after the vowel. /s/ is the only consonant that is equally likely to affect devoicing before or after it. Unlike previous studies, Delforge finds that other voiceless consonants can also trigger the same amount of devoicing as /s/. However, there is a statistically significant difference in devoicing based on the syllabic affiliation of /s/, since it is more likely to take place when the following /s/ is in the coda position,
rather than in the onset of the next syllable or word. Prosodic domain is another factor that can affect devoicing since most, 60% in this study, occurs in word-final position when compared to word medial or initial positions. Additionally, in utterance-final position there is more devoicing of open, word-final syllables (21%) than in intonational phrase-final position (13%).

Delforge (2008a, 2008b) couches her analysis within the Articulatory Phonology framework (Browman and Goldstein 1989, 1992). In order to account for devoicing of all the vowels, which can not be attributed to shortened duration alone, the author proposes that there may be changes in the timing of the glottal opening in the consonant-vowel coarticulation. The difference in timing leads to the glottal opening of the voiceless consonants having an effect on the glottal closing (voicing) of the vowels. To account for gradience and variability, Delforge uses phase windows (Byrd 1996), which specify the amount of overlap between gestures. Rather than just one or two points in time, a range of points is used, i.e. phase windows, within which the vowel and consonant have to overlap. This allows for variability in the amount of coarticulation. However, Delforge mentions that this is a theoretical proposal since she does not have articulatory data. Given that high vowels are typically the ones that are devoiced cross linguistically, Delforge needs to explain why the mid vowels were frequently devoiced in her data, and among the mid vowels why /e/ had higher rates of devoicing than /o/. She attributes this to homorganicity with the voiceless consonant following Lipski (1990). The reduced distance, and increased overlap, between the glottal gestures of the adjacent vowel and consonant segments increases the chances of devoicing. This is more likely to occur with
/e/ since /s/ and /t/, which are both produced in a similar part of the vocal tract as /e/, occur much more frequently than /k/ and /x, which are articulated in the same part as /o/ (2008a:120). The author concludes that perhaps some of the differences between Andean UVD and cross-linguistic trends for the same phenomenon (frequent /e/ devoicing in word medial position, devoicing of all vowels in word-final position and lack of correlation with speech rate) may be a result of contact with Quechua, but this idea is brought up for the first time in the conclusion and it is not further supported or developed with any evidence.

While UVD and unstressed mid vowel raising are two separate processes, the previous research on UVD is relevant to the current study for several reasons. First of all, the mid vowels are frequently reduced, elided, or devoiced, and those are the same vowels that I am analyzing in my study. The reduction, deletion, or devoicing typically occurs in unstressed syllables, which is where vowel raising occurs as well. Furthermore, UVD is a process that can be found in the dialect under study in this dissertation. For this reason, in my own acoustic analysis, vowels that are elided, reduced, or devoiced to the point where it is impossible to measure their formants must be excluded. Additionally, many of the contexts where devoicing occurs, such as in word final position or in a closed syllable, are similar to where mid vowel raising occurs. Thus, the possibility arises of creating a broad category of vowel weakening that encompasses the two distinct processes. I expand on the idea of a Weakening Hypothesis more in section 2.4 in the discussion of vowel weakening processes.
2.3.2 Vowel harmony

Vowel harmony is a process where one vowel triggers a change in the quality of another target vowel. This process affects vowels in many Romance languages resulting mainly in raising or centralization (see Calabrese 1987 and Maiden 1991 for a more detailed explanation of vowel harmony in Italian; Zubizarreta 1979 for Andalusian Spanish, and McCarthy 1984 for Asturian, among others). Here I will focus on changes that affect vowel height in Spanish, although some result in centralization too, while mentioning a few examples from other Ibero-Romance languages as well. The vowel raising process in Colongo also involves changes to vowel height, and I would like to determine whether vowel harmony plays a role or can be ruled out as an explanation. The cases of vowel harmony mentioned in this section either involve a high stressed vowel triggering the raising of surrounding vowels, or other high vowels acting as the trigger to the raising of the stressed vowel.

Hualde (1989), along with others such as Harris (1980) and McCarthy (1984), describes four different types of vowel harmony processes that occur in the Spanish regions of Asturias and Cantabria. In Pasiego Montañés, the final high vowel affects all other vowels in the word resulting in either raising or centralization. Since the final unstressed high back vowels are centralized in this dialect, this causes the other vowels to become centralized as well. Example (1a) illustrates this raising and centralization harmony (the capital letters represent centralization; examples (1)-(3) are all taken from Hualde 1989). The final high vowel causes the stressed mid vowel to raise, as can be seen
in (1b). All mid vowels to the left of the stressed vowel also raise as a result of the change in quality of the stressed vowel from mid to high, which we can see in example (1c). In Tudanca Montañés, the vowels from the end of the word to the stressed vowel are affected by centralization, as shown in (2a). The vowels to the left of the stressed vowel are unaffected. Only an underlyingly high final vowel causes centralization of the stressed vowel, otherwise it does not occur. We can see this difference in (2b) and (2c). A second vowel harmony process occurs in Tudanca Montañés where non-final mid vowels are raised to high when the stressed syllable contains a high vowel or a prevocalic glide. Hualde mentions that there are many lexical exceptions and /a/ is not affected. Also, a final /o/ is not raised when it is a masculine plural marker, a singular marker of non-count mass nouns and adjectives, and a few other non-mass masculine noun exceptions (1989:784). We can see the height harmony in the raising of both pre-tonic syllables in (2d). In Lena Bable, a final high vowel, typically /u/, triggers the raising of only the stressed vowel without affecting the intervening vowels. Thus, in (3a), due to the final /u/ the stressed /a/ raises to /e/, but the intervening unstressed /a/ remains unaffected. These examples illustrate cases of a high vowel acting as a trigger for changes in height or centralization of surrounding vowels. When we consider the case of vowel raising in Mexico, if vowel raising occurs only or mainly in the context of a neighboring high vowel, then it could be considered vowel harmony, and the raising could be seen as resulting from the influence of that high vowel. However, if raising also occurs when there is no high vowel present or in the surrounding environment, this suggests that we are dealing with a distinct process.
In addition to the vowel harmony just discussed, there is also vowel harmony in Andalusia. Hualde (2005:130) explains that there are morphological distinctions between the singular and plural forms in Eastern Andalusian Spanish based on the quality of the final vowel. This dialect has /s/ weakening and this sound is oftentimes deleted from coda position, which means that /s/ is not realized in plural forms. In these cases, what we find is that in singular versus plural forms, the former have a higher or less open final vowel, and the latter have a more open allophone. We see this difference in examples (4) and (5). Additionally, the open or closed quality of the final vowel affects the quality of the stressed vowel and all other vowels in the word, especially if they are mid vowels,
resulting in vowel harmony with respect to openness. In other words, the degree of openness of the final vowel spreads to the left and affects all vowels in the word, which we can see in (6) and (7).

(4) [liβɾo] \(\text{libro}\) ‘book’
(5) [liβɾɔ] \(\text{libros}\) ‘books’
(6) [loβɔɾo] \(\text{lobo}\) ‘wolf’
(7) [lɔβɔɾɔ] \(\text{lobos}\) ‘wolves’

Hualde and Sanders (1995) look at the origin of opening of final vowels in Eastern Andalusia. More precisely, their goal is to determine whether it is an innovation from the loss of /s/ or a separate phenomenon. The authors explain that Eastern Andalusian varieties of Spanish have been described as having, “a greater number of vowel oppositions than in other dialects” (1995:426). Previous researchers point to the loss of /s/ as the reason for the more open final vowel, which is then used to mark the plural due to the absence of the plural consonantal marker. However, Hualde and Sanders question why this does not happen in all dialects with /s/ loss. Their hypothesis is that the singular/plural distinction based on vowel quality occurs in this area, and not others, because there was already a vowel difference at the phonetic level, which existed before the weakening of final /s/. The authors explain that vowel raising in absolute word final position is quite common in this region and is related to vowel harmony, the process in which the tonic vowel acquires the open or closed quality of the final vowel. According
to the authors, with the loss of the final consonant the distinction between open and closed vowels became contrastive.

Hualde and Sanders are able to make some generalizations about changes in singular versus plural vowel realizations by using data from a previous acoustic vowel study of three male university students from Granada (Sanders 1994) and comparing those results to the results from an hour-long recording with an elderly speaker. Both the university students and the elderly speaker had distinct vowel qualities for singular and plural words, but the way in which they distinguished singular and plural words using vowels was not exactly the same. While the mid vowels of the elderly speaker in non-plurals had a tendency to be raised, with an almost high vowel-like quality, the younger speakers did not show this raising. Hualde and Sanders suggest that a recent development in this dialect has been to reduce raising in the singular and increase lowering in the plural, since raising of final vowels is now stigmatized in Spain and is considered a feature of uneducated or uncultured people. Therefore, since laxing (opening) is not stigmatized, there is a reduction of raising in the singular forms and an increase of lowering the mid vowels in the plural forms, which still allows the distinction to remain. This appears to be the strategy that the younger generation has adopted, based on the average formant values of the mid vowels.

Sanders (1998) expands on Hualde and Sanders (1995) by looking at the laxing of vowels in plural nouns and some verbal forms in Eastern Andalusian Spanish in order to outline their inventory and distribution. The author points out that beso ‘kiss’ and besos ‘kisses’ is a minimal pair that “can be distinguished by native speakers of Eastern
Andalusian according to the alternation of open and closed vowels” (1998:110). Sanders prepared a questionnaire with many tri-syllabic vowel combinations (such as *patata* ‘potato’, *zapato* ‘shoe’, etc.), where word-final high vowels were not included because they are not very common in Spanish. 80 tokens were inserted into the carrier phrase “*Digo ... para ti*” ‘I say ... for you’ where the speakers either had the plural or singular word, which was indicated by the definite article. In addition, he recorded some “free conversation” to get more naturalistic data. The vowels of three male university students from Granada were analyzed for F1 and F2 frequencies as well as duration. Results from the 1440 recorded vowels showed a consistent alternation of vowel quality between singular and plural forms for mid vowels in all positions (1998:123). The ANOVA tests confirm that the singular/plural distinction is statistically significant for F1 and F2 in both mid vowels, except in the pre-tonic position, where there is no significant difference in F2 for /o/. Note that we would expect to see a singular/plural distinction in the tonic vowel, based on formant values, since this is a variety that exhibits vowel harmony, although Sanders does not elaborate on this connection. Durational differences are not significantly different for the mid vowels and are a more important feature for the high vowel singular/plural alternation in pre-tonic and tonic positions. Similar results were found for the few minimal pairs that were analyzed from the free conversation. Sanders concludes that the acoustic vowel alternations found in this study are comparable to other languages that make a phonemic distinction. His data further support the idea that laxing is used to make distinctive contrasts in speech, as a marker of plurality, especially in a dialect where /s/ is aspirated or lost completely.
To conclude this section, the phenomenon of vowel harmony is important to keep in mind for the current study when we consider the changes in vowel quality that occur as a result of both vowel harmony and vowel raising. If vowel raising only occurs in the presence of a high vowel acting as a trigger, then the process could be another example of vowel harmony. However, in order to consider unstressed vowel raising as a separate process, there must be instances where it can occur even when there is no high vowel acting as a trigger.

2.3.3 Hiatus resolution

Studies on hiatus resolution (Casali 1998, Jenkins 1999, Aguilar 2003, Alba 2006, Barberia 2012, among others) have found that several strategies are used to change the structure of heterosyllabic vowel sequences. These changes often affect the quality of one of the vowels. These strategies are hiatus maintenance, diphthongization with a high glide, diphthongization with a mid glide, elision of one of the vowels, coalescence (or fusion), and epenthesis. Hiatus maintenance means that the two vowels remain in separate syllables, such as in [te.á.tro] teatro ‘theater’. Diphthongization with a high glide results in a pronunciation of the word peón ‘workman’ as [pjón] (Garrido 2007), where the mid vowel /e/ is raised to the high glide [j], and the two syllables are reduced to one. Diphthongization with a mid glide is similar to the previous strategy except that the mid vowel becomes a mid glide [ɛ] without changing its height. Therefore, the word peón ‘workman’ is pronounced [pɛón]. Elision can affect the first or second vowel in the sequence and results in the pronunciation of only the remaining vowel, such as [le] for lee
‘she/he reads’ (Hernández 2009), which is shortened to one syllable. Coalescence refers to the use of a third vowel, with different features than the two in the hiatus, such as in [lɛskwela] or [lɪskwela] for la escuela ‘the school’ (Jenkins 1999). The last strategy, epenthesis, involves the insertion of a sound in between the two vowels of the hiatus, e.g. [ka.nό.ya] for canoa ‘canoe’ (Garrido 2007). In the following section I discuss several studies that examine hiatus resolution in Spanish in more detail, paying special attention to those that focus on diphthong formation with a high glide using acoustic data. I choose to review this strategy because it involves a change in the quality of the target vowel, and for the purpose of this dissertation I am interested in processes that affect the quality of Spanish vowels. The sections are divided by dialect and I summarize the factors that were found to play a role in the hiatus resolution.

2.3.3.1 Hiatus resolution in Colombia

Garrido (2007) examines /eo/ hiatus, e.g. leopardo ‘leopard’, and /jo/ diphthong sequences, e.g. violencia ‘violence’, and their variation in two dialectal regions of Colombia (Andean and Caribbean) in two different speech styles (reading vs. narration). The author aims to include the social factors that are significant for hiatus resolution, in addition to the linguistic contexts where it occurs. Garrido uses acoustic analysis of the front/back vowel sequence, based on the formant values (F1) and segment duration, to determine whether a sequence of vocoids is produced as a diphthong or as two vowels in hiatus. Based on findings from previous studies, she considers a sequence with longer duration to be a hiatus. She uses the F1 values to determine whether there is a change in
vowel quality, where a lower F1 value in the first part of the vowel sequence is indicative of more diphthongization, i.e. more raising of the mid vowel. 17 university students were chosen for the study, eight from the Andean region and nine from the Caribbean region of Colombia. They read the target words in a carrier sentence, “Digo _____ para ti” ‘I say _____ for you’ and created a narration based on some pictures and the words that accompanied them. Both tasks were recorded. The target words had sequences of the diphthong /jo/, and the hiatus /eo/, in three different stress positions, i.e. pre-tonic, tonic, and post-tonic. Through her acoustic analysis of formant values and duration, Garrido found that the Caribbean speakers were more likely to diphthongize in both tasks. For the Andean speakers, the [eo] sequence was longer, indicating hiatus maintenance, in all stress positions. Additionally, F1 values were higher in both the pre-tonic and tonic positions for Andean speakers, which indicates that the vowel in the sequence is a mid vowel and not a high glide. However, the Andean speakers did diphthongize more in the narration task than the reading task. The statistical analysis showed that the external factor of dialectal region is significant (p < .05). In addition, these dialectal differences were more evident in formal speech. Garrido posits that Caribbean speakers may choose to diphthongize as part of their linguistic identity whereas Andean speakers choose the opposite, since they see diphthongization of hiatus as a stigmatized form. However, a study of attitudes about this feature would need to be performed to provide evidence for any conclusions about the speakers and their linguistic identity.
2.3.3.2 Hiatus resolution in Mexico

Hernández (2009) performs a more comprehensive sociophonetic investigation into the strategies for hiatus resolution, using –ear verbs in Mexican Spanish. In addition to the strategies analyzed by Garrido (2007) of hiatus preservation and diphthongization with a high glide, Hernández also considers diphthongization with a mid glide, elision of one of the vowels, and vowel fusion. She incorporates acoustic analysis of the first two formants to determine the quality of the vowels and statistical analysis to determine which linguistic and external factors are statistically significant for each strategy. She uses the “friend of a friend” method to find 38 informants in Chetumal, Quintana Roo, Mexico. She conducted three types of tasks which were a sociolinguistic interview, a repetition/reconstruction task, and a transformation task. In the second task, the informants heard audio recordings of sentences which were partially distorted with white noise during the vowel sequences of interest. With the help of accompanying pictures, they had to repeat what they heard. In the third task, participants were presented with three cards, which they would use to create a sentence, after conjugating the verb. The linguistic variables that she analyzed were: the quality of the following vowel in the vowel sequence ([a], [e], [o]), where the stressed syllable is in relation to the two vowels (the first vowel is stressed, the second vowel is stressed, or the vowel in the next syllable is stressed), the sonority of the vowels (rising or constant), the verbal form (simple present, simple past, simple future, imperfect, gerund, infinitive, participle, and the imperative/subjunctive), and whether the syllable is open or closed. The external
variables that Hernández takes into account are: method of data collection (interview, repetition/reconstruction task, transformational task), age (18-24, 25-35, 36-55, 56-65), gender, and education level (primary and middle school, high school, university). The three resolution strategies that were found to be most significant were: diphthong formation with a mid vowel (39%), hiatus preservation (28%), and diphthong formation with a high vowel (21%). I will now discuss the most relevant factors for each strategy individually.

Diphthong formation with a mid vowel was the most commonly used strategy. The factors that favored its use were: stress, sonority, age, method of data collection, education level, and gender. The most significant variable was stress, with the combined category of a stressed second or third syllable favoring this mid vowel diphthong formation. When considered separately, the diphthongization tends to occur more frequently when the stress is on the syllable following the original hiatus. The author proposes that the further away the stressed syllable is from the vowel sequence, the more likely it is that this strategy will be used. For example, *pasearé* ‘I will go for a stroll’ will be more likely to have a diphthong than *paseo* ‘I stroll’ or *paseó* ‘he/she strolled’. Raising sonority, rather than constant sonority, also favored this strategy. Both the sociolinguistic interview and the transformation task, the first more than the second, favored the formation of a mid vowel diphthong. Of the four age groups considered, the two youngest groups favored this strategy. Men and participants with university education tended to prefer mid vowel diphthong formation as well.
Hiatus preservation was the second most frequently used strategy and the factors that were found to favor its use were: stress, sonority, method of data collection, and age. Stress was found to be the most significant variable for this strategy, with stress on the first vowel, /e/, highly favoring preservation of the hiatus. An example of this would be the word *pasean* ‘they stroll’. Raising sonority between the two vowels also favors hiatus preservation. The repetition/reconstruction task and transformation task were combined and slightly favor hiatus preservation over the use in the sociolinguistic interview. The two older groups and the youngest group favor hiatus preservation.

The third most used strategy was diphthong formation with a high vowel and the factors that favored its use were: stress, syllable type, age, education, and gender. A stressed second syllable highly favored this strategy while stress on the third syllable neither favored nor disfavored the use. Open syllables slightly favored high vowel diphthong formation over closed syllables. In the age groups, the oldest group and the second youngest group favored the use of this strategy over the two others. The participants with the lowest education level favored diphthong formation with a high vowel, as did the women.

Hernández proposes that the stigmatization associated with high vowel diphthong formation in *-ear* verbs of speakers of Chetumal Spanish has made it more socially stratified, which is evidenced by its use by older and less educated people. A new strategy appears to have emerged, diphthong formation with a mid vowel, which is a middle ground between the standard form with a hiatus and the stigmatized form of diphthongization with a high glide. This is the most common hiatus resolution strategy.
and was favored in general by her participants with more education, males, and the youngest age groups, which suggests a change in progress.

These studies on hiatus resolution show that vowel quality changes can occur when there are two adjacent vowels in heterosyllabic sequences. Their findings are especially important to the current study because there may be tokens from my own data where the final mid vowel is part of a hiatus sequence, such as the word feo ‘ugly’. Since the first vowel is typically the one that is most likely to change quality in hiatus resolution, this should not present a problem for tokens like feo ‘ugly’. However, a final unstressed vowel that is followed by another vowel, as in come éstas ‘how are you’ or quiero otros ‘I want other ones’, may be problematic for the current study since Barberia (2012) found more hiatus resolution strategies across word boundaries than within a single word. As such, tokens followed by another vowel will be excluded, as discussed further in section 3.2, to ensure that the focus of the present study is on unstressed vowel raising and not hiatus resolution.

2.3.4 Variation in vowel production due to language contact

Dialectal variation in vowel systems has also been examined as a result of language contact. This variation can take several forms, including raising and changes to the vowel space. The contact with other languages may have an influence on the production of Spanish vowels as we will see in the following studies which focus on Ecuador, Peru, Spain, and the Southwest of the United States. However, it should be kept in mind that these changes are typically in the vowels of bilinguals in these studies. Other
motivations will need to be proposed for the same kinds of changes in varieties without language contact such as in the case of Michoacán under investigation here.

2.3.4.1 Variation in vowel production due to language contact in Ecuador

Guion (2003) compares the vowel system of monolingual Spanish speakers to that of Kichwa-Spanish bilinguals in highland Ecuador. The bilinguals were grouped according to the age of acquisition of Spanish, resulting in four groups: simultaneous, early, mid, and late bilinguals. This study focuses on the production of vowels and as such, the participants listened to and repeated the target words in carrier phrases. The bilingual groups, with five speakers per group, did this task in both Kichwa and Spanish whereas the monolingual group did it only in Spanish. The target phrases were “_____ nipai” ‘say _____’ for Kichwa and “_____ es la próxima palabra” ‘_____ is the next word’ in Spanish. The author analyzed a total of 1,480 words from 25 speakers, looking at the first three formants. Her results confirmed her hypothesis that earlier exposure to another language is more likely to lead to acquisition and native-like production of second language vowels. This was the case for the simultaneous bilinguals, most early bilinguals and about half of the mid group. There was an influence on L1 in these groups (Spanish influence on Kichwa), since their Kichwa high vowels were produced higher than Kichwa monolinguals. The late bilinguals and the other half of the mid bilinguals did not appear to be differentiating their vowels for Kichwa and Spanish. This study confirms that language contact will affect L1 and L2 differently, depending on the age of acquisition. Guion’s results also suggest that when exploring the factors that influence
vowel raising, language contact should be considered since she has shown that language contact can affect the vowel space. The possibility of language contact in the Colongo community will be discussed in 2.3.5.5 in the concluding remarks of the section on unstressed vowel raising in Mexico.

2.3.4.2 Variation in vowel production through language contact in Peru

O’Rourke (2010) looks at the influence of Quechua on the Spanish vowels of monolinguals and bilinguals in Peru. She worked with monolingual speakers from Lima and Cuzco, and simultaneous bilinguals and L2 Spanish speakers from Cuzco. She had speakers from each of the four groups read from index cards and at least 10 stressed vowel productions were acoustically analyzed for each speaker. Through her analysis of the first three formants, O’Rourke found that Cuzco speakers have a larger and more fronted vowel space than Lima speakers. The three Cuzco groups acted differently, with the L2 Spanish group having the largest vowel space. In their organization, Cuzco speakers in general had the mid vowels closer to the high vowels than to /a/, but no overlap among these vowel qualities. There is no vowel inventory reduction, as both Cuzco and Lima speakers maintain five distinct vowels. L2 Spanish speakers had greater backness for back vowels and the simultaneous bilinguals had front vowels that were farther back than the other two groups.

An /i/ produced in Lima has the same frontness as /e/ for Cuzco L1 and L2 groups, which, according to O’Rourke, may be why a Cuzco speaker producing /e/ is perceived as producing /i/ by Lima listeners, because of the higher F2 value. Just as
Guion (2003) found, there can be differences in the vowel space of bilinguals depending on whether they are simultaneous or late second language learners. In this study, L2 learners were actually more similar to L1, especially with front vowels, than the simultaneous bilinguals. O’Rourke establishes how the vowel space can vary among speakers in the same region, especially with the influence of language contact. Additionally, the author shows that it is this difference in vowel space, and not what has been proposed as a neutralization of mid and high vowels by Quechua-Spanish bilinguals, negatively deemed *motosidad*, that creates the perception of different vowels in bilinguals.

2.3.4.3 Variation in vowel production through language contact in Spain

Barnes (2013) examines the influence of Asturian features in the Spanish vowels of her participants in Asturias, Spain. Although both production and perception data are considered in her dissertation, I will limit the discussion here to the vowel production portion, as that is the most relevant for the current study. The author conducted 24 sociolinguistic interviews, with 12 women and 12 men, who ranged in age from 25 to 60 years old (2013: 78). The participants were recruited using the “friend of a friend” method. By performing an acoustic analysis of the target vowels, Barnes provides both a categorical and continuous analysis of /o/ and /as/ based on the measurement of the formant values. The author uses a Discriminant Analysis of Principal Components (DAPC) (Jombart 2008, Jombart, Devillard and Balloux 2010) to create a categorical raising distinction, i.e. raised or non-raised, based on the formant value measurements.
discuss this method in more detail and how it is used in the current dissertation in section 4.1.1. The author examines the variation in Spanish masculine singular words where final /o/ can be produced as [u] and in feminine plural words where final /as/ can be pronounced as [es] as a result of Asturian influence. She considers linguistic variables such as the quality of the stressed vowel, stress pattern, preceding segment, lexical category, prior form (whether it was a Spanish or Asturian lexical item), and following segment, among others.

Barnes found that the preceding and following segments had a significant effect on raising, where articulations further back in the mouth favored the use of [u] over [o] and a preceding palatal segment favored the use of [es] over [as]. The prior form was also a significant predictor, where a prior [u] favored the use of [u] and a prior [es] favored the use of another production of [es]. Additionally, for the /as/ variable, raising was more likely for determiners than any other lexical category. Barnes also considered social variables and found that speakers were more likely to use raised variants when they had a lower education level, worked in commerce or manufacturing versus an administrative occupation, and, for the /o/ variable, raising was more likely in men. This study is relevant for the current dissertation because of its innovative methodology and findings regarding both linguistic and social factors that favor vowel raising in this variety. However, the influence of language contact in this community and the bilingual capacities of the participants must be considered before comparing these results to other varieties of Spanish with vowel raising such as Mexican Spanish.
2.3.4.4 Variation in vowel production through language contact in the Southwest of the United States

Willis (2005) analyzes the vowel system of four female Spanish-English bilingual speakers in the U.S./Mexico border area, who spoke Spanish at home and learned English in school. He refers to their Spanish as Southwest Spanish (SWS). He took their vowel productions from a narrative that they created to go along with the book, *Frog, where are you?* Since the author had found these same speakers to have a larger vowel space when reading as opposed to more spontaneous speech, he focused on the first five stressed occurrences of each vowel from the narrative. He also compared stressed and unstressed realizations of /a/ in order to test whether there was any centralization or reduction to schwa in the unstressed position as occurs in English. Willis found that the values for F1 and F2 for these speakers were significantly different than what had been found by Quilis and Esgueva (1983) for Mexican speakers. The author concludes that the SWS vowel system is more centralized and fronted than the Mexican one. Also, the high SWS vowels are lower, almost at the same values as standard Spanish mid vowels, although there is no overlap since SWS mid vowels are lower as well. Finally, Willis also concludes that stress does not seem to play a role in the production of /a/ (2005:194). When considering these results it is important to take into account the contact situation with another language, English in this case, which could have an effect on vowel production. This study is important because it shows that there is more vowel variation than previously
thought and this variation may depend on factors such as language contact and/or the type of methodology used to obtain the data.

The studies discussed in this section have shown the importance of considering language contact when exploring changes to the vocalic system. The possibility of language contact as a reason for unstressed vowel raising in Colongo will be discussed at the end of the following section (2.3.5) where unstressed vowel raising in Mexican Spanish is examined.

2.3.5 Unstressed vowel raising

Unstressed vowel raising has been studied to a varying degree in several varieties of Spanish. Typically this refers to the raising of any of the pre-tonic or post-tonic vowels in words with more than one syllable. In the following sections I will discuss unstressed vowel raising in Judeo-Spanish, Colombia, northwestern Spain, Puerto Rico, and Mexico. I focus on these dialects because I have found studies that offer descriptions of vowel raising in these regions. For additional mentions of unstressed vowel raising see Alvar (1959) for the Canary Islands, Spain, Post (1934) for southern Arizona, and Espinosa (1930) for New Mexico. In some dialects this involves mid vowels being raised to high vowels and in others a low vowel can raise to a mid vowel as well. The following studies show that the frequency of raising varies among dialects. I will concentrate on the process of unstressed vowel raising and the factors that influence it, because the results from prior research provide motivation for the factors explored in the current study.
2.3.5.1 Unstressed vowel raising in Judeo-Spanish

Luria (1930) examines Judeo-Spanish by collecting written data from the Monastir dialect in Yugoslavia (modern-day Macedonia) complemented by conversations with speakers of this dialect in New York. He performs a thorough analysis of the dialect, focusing on phonology, morphology, syntax and vocabulary, but I present only the findings that are relevant to vowel raising. Luria finds that tonic /e/ and /o/ tend to diphthongize, for example *dientru* for *dentro* ‘within’ (1930:97). Pre-tonic mid vowels are pronounced as their raised counterparts, which results in words like *dizir* for *decir* ‘to say’ and *cumér* for *comer* ‘to eat’ (1930:99-100). He also notes that final low and mid vowels tend to raise, especially in an open syllable or followed by /s/ or /n/. Several examples of final vowel raising in Judeo-Spanish are shown in table 4, which illustrates that not only can mid vowel raising occur in both pre-tonic and post-tonic positions in Judeo-Spanish, but there is evidence of low vowel raising in post-tonic position as well. Luria provides us with a detailed description and examples that demonstrate how raising occurs, but unfortunately there are no other studies analyzing this phenomenon in this dialect that I am aware of.

<table>
<thead>
<tr>
<th>Monastir dialect</th>
<th>Modern Spanish</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>caze</td>
<td>casa</td>
<td>‘house’</td>
</tr>
<tr>
<td>cazes</td>
<td>casas</td>
<td>‘houses’</td>
</tr>
<tr>
<td>comis</td>
<td>comes</td>
<td>‘you eat’</td>
</tr>
<tr>
<td>comin</td>
<td>comen</td>
<td>‘they eat’</td>
</tr>
<tr>
<td>sincu</td>
<td>cinco</td>
<td>‘five’</td>
</tr>
<tr>
<td>favlu</td>
<td>hablo</td>
<td>‘I talk’</td>
</tr>
</tbody>
</table>

Table 4: Selected examples of vowel raising in Judeo-Spanish from Luria (1930:100-102)
2.3.5.2 Unstressed vowel raising in Colombia

Flórez (1951) addresses vowel raising in Colombia in his book which focuses on Spanish pronunciation in Bogotá. He collected auditory data in the mid to late 1940s in various public places and from his interactions with people from all levels of society. For the unstressed vowels, he focuses mostly on examples of what he calls “changes,” i.e. the pronunciation of a different vowel than what is expected from explanations of typical Spanish vowels. I focus here on the instances of raising. He gives examples for each vowel in differing positions of stress. In pre-tonic position he mentions cheleco for chaleco ‘vest’, prisente for presente ‘present’, and muchila for mochila ‘backpack’ (1951:46-49). He does talk specifically about the frequency of mid vowel raising in word-final position. Flórez notices that the raising of /o/ to [u] is frequent and very noticeable in people from Antioquia, Caldas, Cauca, Nariño, and Norte de Santander (1951:77). He points out that [u] instead of /o/ can even be heard in careful speech and from more educated people, not only in word-final position before a pause, but even in word-final position within a phrase. He lists examples of raising from speech as well as literary texts such as: cincu ‘five’, quietu ‘quiet’, enfermu ‘sick’, peru ‘but’, and muchachu ‘young boy’ (1951:77-78). Flórez adds that this does not only occur in open syllables, since it happens in the plural forms as well. He goes on to explain that the word-final raising of /e/ to [i] also occurs, especially in Caldas, but not as frequently as the back mid vowel raising. He provides the example, esi for ese ‘that (one)’ (1951:78). He explains that this is a relatively common occurrence in Romance languages including
parts of Spain, the mountains in Ecuador, Puerto Rico, etc. Although we do not have all the details, this study documents the vowel raising process in Colombian Spanish.

2.3.5.3 Unstressed vowel raising in northwestern Spain

Holmquist (1985) analyzes the Spanish in Ucieda, located in northwestern Spain, where the variety of Spanish is usually referred to as montañés. He studies the tendency for the mid vowels to be raised to high vowels, especially in word-final position. Holmquist gives the examples of [le.tʃi] leche ‘mil’ and [po.θu] pozo ‘well’, and he adds that metaphony of the tonic vowels before final high vowels is also common. He notes that, “especially noticeable in their speech is the frequent use of u in word-final position where in Castilian one finds o” (1985:192). Thus, of the two mid vowels that might be raised, it is more commonly the back vowel that undergoes this change. People from this village are aware that they speak Spanish differently than people from other regions of Spain and have a saying, “Hablamos castellanu con la u” that roughly translates to ‘We speak Spanish with a u’ (1985:193). This is in reference to the frequent pronunciation of [u] in place of /o/. Holmquist conducted 50 interviews, part of which was a lexical questionnaire. He considered only external variables such as age, occupational group, ownership of mountain animals, and gender. Holmquist found that older generations are more likely to produce raised vowels than younger generations. Farmers and people who own mountain animals are also more likely to produce raised vowels. Holmquist suggests that the younger generations have vowel raising less frequently due to their industrialized, modern lifestyle, rather than the farming lifestyle of their elders. Women
are closer to the prestige form than men, since they reject the dialect associated with the land. Politically, centrists use more [o] and independents use more [u] (1985:201). Holmquist concludes that his study shows how vowel raising is dying out with the younger generations in this area as they aim for the more prestigious standard. Moreover, this study shows that quantitative analysis is a useful tool even in small communities because the results present a clear social stratification. The community under study is in an area of language contact, so it is interesting to note that this factor was not mentioned as a possible influence on vowel raising. Barnes (2013), in a study on the contact between Asturian and Spanish, discussed in section 2.3.4.3, finds that the use of the Asturian high back vowel in Spanish, instead of the Spanish mid vowel, reveals a sense of regional identity. This use of high vowels in place of mid vowels can be seen as another form of unstressed vowel raising as a result of language contact. This interaction of language contact with vowel raising should be considered for the Holmquist study as well since it is located within a similar contact situation.

2.3.5.4 Unstressed vowel raising in Puerto Rico

Vowel raising in Puerto Rico has been studied by several researchers. Navarro Tomás (1948) discusses mid vowel raising in the western part of the island, particularly in word-final position. His impressionistic analysis comes from listening to how people speak as they answered questions from his questionnaire. He determines that final mid vowels tend to be pronounced like a high vowel when preceded by a stressed high vowel, such as in (8-10, and 14), or a diphthong, as seen in (11-12) (1948:48). The author
suggests that if the stressed vowel is /a/, then the mid vowels are more likely to remain mid vowels. On the other hand, he does mention that there are some cases of raising after a stressed /a/, such as (13), which suggest that this process is not the same as vowel harmony, since /a/ is not a high vowel. Vowel raising is also favored after a palatal consonant, as seen in (14-15). Navarro Tomás presents a possible link to older farming families that came over from Asturias and Galicia and points out that vowel raising is considered “pronunciación campesina” ‘farmer pronunciation’ (1948:50).

(8) dúlc[i]  
(9) píd[i]  
(10) carrí[t]u  
(11) puént[i]  
(12) véint[i]  
(13) cáld[u]  
(14) púñ[u]  
(15) léch[i]

dulce ‘sweet’
pide ‘she/he asks’
carrito ‘little car’
puente ‘bridge’
veinte ‘twenty’
caldo ‘broth’
puño ‘fist’
leche ‘milk’

Holmquist (1998) examines vowel raising in men’s speech in a rural agricultural community in Puerto Rico, Castañer. He analyzed 60 sociolinguistic interviews, which were obtained from his host family or their relatives and through the “friend of a friend” method. When working with the 30 male interviews, some of the social variables that he studied were employment, length of time in and out of the community, membership in
social groups, and education. Although he discusses a three-way distinction between mid, raised (mid), and high vowels, he does not explain exactly how this distinction is established, though one can guess that it is from an auditory impressionistic analysis. Throughout the paper he generally refers only to mid or high vowels, so it is not clear whether he groups the “raised” and “high” vowels together or considers them separately.

Holmquist found that farmers tend to have a higher rate of vowel raising than other occupational groups, which corresponds with what he found in northwest Spain. Holmquist tested whether two phonological factors favor vowel raising: a high tonic vowel in the preceding syllable (such as in dice ‘he/she says’), or a preceding palatal consonant (as in oché ‘eight’). His findings coincided with those of Navarro Tomás (1948) and vowel raising was favored in both contexts. The author found a tendency for more vowel raising of back vowels than front vowels. He also found that a preceding high glide had a positive effect, but not to the extent that high vowels did, and so did a preceding palatal consonant. Holmquist additionally explores the “morphological category” of the words and found that raised vowels are less likely to be found in words that do not belong to what he calls nominal or verbal categories. Aside from those two categories, he has a third category, which he labels “other.” There he includes words such as donde ‘where’ and este ‘umm’ and all other words that do not fit into the nominal or verbal categories.

Holmquist uses social factors to group the males into networks. He gave each individual a score based on the following four factors: 1) length of time spent away from Castañer, 2) membership in local groups and institutions, 3) education (primary school or
less, secondary school, post-secondary school, and post-secondary school outside of Castañer), and 4) employment (agricultural, nonagricultural or commercial, and professional) (1998:76). Although he explains that the highest scorers were considered part of the “dense” network and the lowest were part of the “open” network, he does not describe how the scores were derived. He concludes that dense networks of males are more likely to have vowel raising and open networks can have it when they shift styles to the local style.

Holmquist (2005) then examines five phonological features that are characteristic of the women in Castañer. I will discuss only his analysis of mid vowel raising. The author focuses on the differences among three generations (under 40, 40-65, 65+) where he has 10 participants from each of the three groups, half from an open network and half from a dense or closed network. He uses similar criteria for network membership as he used in Holmquist (1998). The difference is in the fourth factor, which in this study is membership in a family whose income comes mainly from coffee cultivation. A second sample of women explores the employment of the middle generational group in a sample of 20 women (five each from farming, local business, local school, or hospital) and five return immigrants who had worked elsewhere (2005:110). There were 120 tokens per speaker that were either raised mid vowels or mid vowels that were raised to high, using his three way distinction. Interestingly, Holmquist (2005:110) points out that “the high and raised-mid variants of the front- and back- vowel variables are not the most frequent in the data.” So, although the majority of the words examined do not have a raised vowel, his focus is on which factors favor raising when it does happen. In this study, the
percentage of raising for the two variables is similar, 40% for /e/ and 38% for /o/, when including both the high and raised variants. However, if we include only the high vowels, then there is more /o/ raising, 28%, than /e/ raising, 21%. The results for the preceding linguistic context are similar to what was found in Holmquist (1998), a preceding high tonic vowel or preceding palatal consonant favor raising, although the percentages are a little higher in this study. A Varbrul analysis shows that in word-final position both high vowels are favored by the oldest group, slightly favored by the middle age group, and favored in the closed network. He then breaks down some of the external factors used to determine the network membership and analyzes educational experience and time spent in Castañer separately. The figures used to represent the results show a correlation of high vowel use with higher age, lower education and more time spent in Castañer. The Varbrul analysis in the appendix shows the data a little differently because the Varbul results do now show the same linear trajectory suggested in the figures, especially in the case of time spent in Castañer. For the front high vowel, primary school education favors its use, but secondary neither favors nor disfavors, and post-secondary education disfavors its use. The results are similar for the back vowel, although secondary education disfavors the use of the high back variant. Both high vowels show a similar pattern for time spent in Castañer where “much” or “less” time favors vowel raising, but “little” time disfavors it. It is interesting to note that the “less” time in Castañer group favors the use of the high variants slightly more than the “much” group for both mid vowels. Unfortunately there is no detailed explanation about how exactly these three different groups were determined, but it seems that the order is “much,” then “less,” then
“little,” indicating the amount of time spent in Castañer. In the second sample, where the women were grouped by occupation, the figure shows that women involved in farming or dealing with farmers have more vowel raising than the other occupations. The Varbrul analysis confirms that farmers slightly favor the use of the high variants over non-farmers. Holmquist concludes that although the women and men are analyzed differently, the results of both the patterns and frequencies are very similar for the two groups.

Oliver Rajan (2007, 2008) adds to the research on vowel raising in the coffee zone of Puerto Rico by conducting an auditory impressionistic study, verified by some acoustic analysis, of the vowels involved. Oliver Rajan (2007), based on 69 sociolinguistic interviews with 29 females and 40 males, focuses on mobility, and other social factors, and how these affect the change in vowel production. She suggests that speakers may adopt a different standard of speech than used in their community, more similar to where they study, work, etc., in order to fit in or move up on the social scale. So, those with more mobility would have less vowel raising. The extralinguistic variables she considered were gender, age, employment, education, and mobility. She created a mobility scale where participants who had left the coffee zone were categorized as having mobility and those who had never left had less mobility. The author made a binary distinction where the “never out” group was born and raised in the coffee zone and never moved away, and the “out” group had moved out of the coffee zone, typically for work or study, for more than two years. However, there is no indication of what would happen to participants that had moved out of the coffee zone for less than two years, or why two years away was determined to be the distinguishing factor. Oliver Rajan’s results
corroborate the findings of Holmquist (1998, 2005), that back mid vowel raising is more frequent than front and that raising is favored in older generations, those with less education, and those who have not left the community. The author concludes that overall there is no significant difference in vowel raising between males and females, age is an important factor, and since younger generations have less vowel raising, this feature could eventually disappear.

In her much more elaborate sociophonological analysis, Oliver Rajan (2008) explains that she analyzed the last 15 minutes of the 69 interviews and took 100 tokens per subject, half of the front variable and half of the back variable, for a grand total of 6900 tokens. The social variables analyzed were age, gender, occupation, education, and mobility, which are the same as those analyzed by Holmquist (1998, 2005). However, her age factor was different since it included both children and adolescents. She found that mobility is the most influential factor and, using the same mobility scale from her previous study, those with more mobility are less likely to have vowel raising. Vowel raising increases with age, but there is not a significant difference for males and females. People with less education are more likely to have vowel raising than those with more education. Occupation follows the same trend as education with coffee pickers and homemakers showing more vowel raising than teachers or hacendados 'land-owners'. Oliver Rajan found raising 16% of the time for the front mid vowels and 21% of the time for the back mid vowels, which was a significant difference between the two (p<.001). Overall the vowel raising feature occurs about 18% of the time. The other linguistic variables that she analyzed were grammatical category (nouns, verbs, adjectives, adverbs,
prepositions, and other (pronouns, interjections, conjunctions)), number of syllables (2-7), type of onset (based on articulation), type of stress (paroxytone, proparoxytone), and vocoid to the left (vowels or glides). I will present the most significant results from these factors. The difference between front and back vowel raising by grammatical category is significant only for verbs and adjectives, where back vowel raising is favored. Words with four syllables have more vowel raising than all other syllables when the two mid vowels are considered together (such as buscándome ‘looking for me’ or sacrificio ‘sacrifice’) and there is a significant difference in raising between the two mid vowels for words with three, four, or five syllables. Vowel raising is highest for both front and back vowels in words with antepenultimate stress (such as fíjate ‘notice (2 sg. imperative)’ and último ‘last’), when compared to penultimate stress. Both variables are most likely to raise when preceded by [j], [i], or [a]. Finally, words with a deleted onset or no onset at all have the highest vowel raising rates for both vowels when compared to other types of onsets.

Another interesting finding and analysis from this study is the explanation that unstressed vowels in the last metric foot of a word domain can raise. This accounts for all raising, but is especially important to explain cases that have not been analyzed previously where the vowel raising occurs in positions that are not word-final. For example, [gwajándulu] guayándolo ‘grating it’, [dihpwéh] después ‘after’, [djáɣwa] de agua ‘of water’, and [ilsákuési] el saco ese ‘that coat’ (Oliver Rajan 2008:202-204). These types of examples point to the importance of taking stress into account. The author also includes a few examples to show that vowel raising also can occur in closed
syllables, such as [pahtélih] pasteleś ‘pastries’ and [aβésih] a vezec ‘sometimes’.

Crucially, the previous examples point out that vowel raising is occurring in more contexts than originally thought. Although Oliver Rajan does not provide a statistical analysis of the difference between raised vowels in final or non-final post-tonic position, she does demonstrate that post-tonic non-final vowel raising does occur, and this had not been addressed in previous research.

2.3.5.5 Unstressed vowel raising in Mexico

Vowel raising in Mexican Spanish has not been as thoroughly investigated, although it is mentioned by several researchers. In a monograph about the speech of Guanajuato, a neighboring state of Michoacán, Boyd-Bowman (1960) makes an impressionistic analysis based on the speech of informants from various social levels. In the section on vowels, he describes the raising of word-final vowels. The author explains that in the cities of Guanajuato and Romita there is a closed quality to the final mid vowels making them sound like high vowels. However, this does not occur in all final mid vowels, so there is variation. Boyd-Bowman expresses, “Tenemos informe oral de que la –u y la –i finales predominan en Michoacán y en otras partes del estado de Guanajuato…” ‘We have oral evidence that final /u/ and /i/ are prevalent in Michoacán and in other parts of the state of Guanajuato’ (1960:37). Some of the examples he provides are (where I indicate the stressed vowel): chicuc for chicos ‘kids’, de tódus módus for de todos modos ‘anyway’, cuáti for cuate ‘buddy’, adelánti for adelante ‘further on’. He finds that vowel raising is more common after a palatal consonant and is
not restricted to any particular social class as it is heard just as much in rural
environments as it is in the city. Cárdenas (1967) also describes final vowel raising in his
book on the Spanish of Jalisco. The author mentions that final unstressed /e/ is the most
likely to have any changes, such as raising after a palatal consonant as in the words noche
‘night’ and coche ‘car’.

In a tribute to Iorgu Iordan, who previously described the behavior of unstressed mid vowels in Spanish spoken in the Americas, Lope Blanch (1979) specifically addresses final mid vowel closure in his study that takes place in Michoacán. His data comes from questionnaires that were administered in several cities within the state, including Morelia, Zacapu, Gurachita, and Zamora, among others. Although there is not much description of how the data was collected, it seems that these were oral questionnaires where the participants had to pronounce a prepared list of words and the investigator decided whether or not there was raising. The goal was to find the linguistic contexts that favor raising. Out of the 802 instances where the vowels were transcribed as raised, 288 were preceded by a palatal consonant. Thus, it is more likely for raising to occur after a palatal than after another consonant in this data. The next most likely raising context is the back vowel after a velar consonant, which suggests that assimilation in point of articulation may be an important factor for raising. For palatal or velar consonants, the body of the tongue raises to reach either the hard or soft palate, respectively. The higher position of the tongue from the previous consonant may also cause the following vowel to be produced higher in the mouth as a result. These results coincide with previous research suggesting that a previous palatal favors raising, but also
highlight the existence of raising in other contexts as well. Based on the statistics provided, it seems that the numbers suggest that vowel raising occurs more with the back vowel, but it is important to note that there were more words ending in /o/, 553 occurrences, than in /e/, 249 occurrences. Both Lope Blanch and Iordan attribute final vowel closure to the weakened articulatory force in the word-final position. Lope Blanch adds that this closure is even more common before a pause, which happens to be the same position where devoicing commonly occurs with vowels and even some consonants, as discussed in section 2.3.

Moreno de Alba (1994) presents data from the *Atlas lingüístico de México* (ALM) ‘Linguistic Atlas of Mexico’. He shows that mid vowel closure happens frequently in several states, including Michoacán. His findings suggest that /o/ closure occurs with more frequency and in more places than /e/ closure. Moreno de Alba concludes that there tends to be an inverse relationship between frequency of vowel closure and socio-cultural level, since raising is more frequent in illiterate or semiliterate people than in middle or upper class people (1994:47). Note that the socio-cultural level as the term is used in Spanish typically includes a reference to education.

Parodi and Santa Ana (1997), in an article describing speech communities in the rural areas around Zamora, Michoacán, Mexico, discuss how a certain set of features can distinguish speakers of rural Michoacán Spanish from speakers from other areas of Mexico. One of these regional features for Michoacán, the most relevant for the current project, includes what they call the closing of mid vowels, or the raising from mid to high of unstressed vowels. Parodi and Santa Ana (1997:315) provide the following examples:
[ká.ji] calle ‘street’ and [pó.kus] pocos ‘few’. Since their work has a broader focus on speech communities, Parodi and Santa Ana do not attempt to explain this feature in detail. Parodi (2001) also makes mention of the closure of mid vowels as a regional feature of Michoacán in her article about language contact in the Americas. The author characterizes the use of vowel alternations as one of the features of the typical speech of a ranchero ‘rancher’.

In several of the previous studies (in section 2.3.4) we saw that contact with another language can have an effect on vowel production. In the case of rural Michoacán Spanish, however, there is no current contact with another language except an occasional, brief, indigenous presence during the town’s annual celebration. I have explored the possibility that the indigenous language Tarascan, also known as Purépecha or Tarasco, has had a past influence on the Spanish spoken in Colongo. There are a few studies that either examine the Tarascan language or its influence in Michoacán (Crisóstomo Nájera 1944, Boyd 1969, Friedrich 1971a, 1971b, Hamel and Francis 2006). Ragone and Marr (2006) examine fourteen communities in Michoacán to determine the extent of Purépecha language maintenance through a series of interviews involving both linguistic and geographic information. The authors report that there are approximately 96,000 monolingual and bilingual Purépecha speakers, which are mainly located in the “Meseta Purépecha” region. Ragone and Marr found more use of Purépecha in the Meseta, where they claim there is a Spanish/Purépecha diglossia, than in the capital city of Morelia, where there is little influence of Purépecha. They explain that in the Meseta, Spanish is
used as the form of communication outside of the community and Purépecha is the home language used within the community. There is a recent interest in teaching Purépecha in school in these communities, in addition to a sense of pride in their culture and traditions, and Spanish is taught as a second language that is necessary for outside interactions and continuing education. The authors conclude that Purépecha use has stabilized in the region and that urbanization and commerce are factors that contribute to increased use of Spanish. Although several of the Purépecha words from Ragone and Marr’s study were recognized by one former resident of Colongo, unfortunately there is not enough evidence to present a strong case that vowel raising is a result of contact, past or present, with the indigenous people. At this point, the variation in vowel production appears less likely to be due to past language contact and more comparable to other cases of unstressed vowel raising, such as in Puerto Rico.

After a thorough review of the previous studies on vowels, and especially vowel production in Mexico, it is clear that a systematic investigation of vowel raising is missing from the literature. Most notably lacking is the acoustic evidence for vowel raising and a complete description of the contexts where it occurs in Mexico. There are several studies, such as Navarro Tomás (1948), Holmquist (1998, 2005), and Oliver Rajan (2007, 2008), that will inform the choice of variables in my own vowel raising study. I will now present a brief summary of the relevant factors that affect vowel raising, which have been discussed in the previous sections. A tonic high vowel, preceding high glide, or a palatal consonant have been shown to favor raising. Other linguistic factors such as the number of syllables in the word, the type of stress (penultimate, etc.), the
syllable onset, whether or not the vowel is in an open or closed syllable, the lexical category, and a non word-final position have been shown to influence vowel raising. As for the social factors, raising is influenced by age, education level, mobility, and the type of social networks the individual is in. I will use these factors as a starting point because they may prove to be important in my own analysis. At the same time, I will also introduce new variables to the current study on vowel raising in rural Michoacán to determine whether or not additional factors may be influential. Each of the independent variables will be discussed in detail in section 3.4.2.

2.4 Vowel weakening processes

Vowel weakening can refer to a reduction in the vowel system, a reduction in duration, or a reduction in sonority, among other interpretations. In this section, I argue that vowel raising can be seen as another type of vowel weakening process based on the reduction in contrasts combined with the reduction in duration that result from this raising phenomenon (see chapter 1). In order to explain my results within a vowel weakening framework, and support my Weakening Hypothesis, it is important to first review previous analyses that have been proposed to account for vowel weakening. In this section, I focus on vowel weakening theories with a special emphasis on raising in unstressed positions, since those are the most relevant to the current study, (see Lindblom 1963, de Graaf 1987, Duke 1993, Steriade 1995, 1997, and Crosswhite 2001 for further work on vowel weakening) before elaborating on my Weakening Hypothesis.
Flemming (2004) analyzes vowel weakening within his Dispersion Theory framework, which connects the notions of contrast and perceptual distinctiveness. More precisely, the selection of phonological contrasts is guided by three goals: 1) maximize the distinctiveness of contrasts, 2) minimize articulatory effort, and 3) maximize the number of contrasts (2004:236). These goals are in conflict, and Flemming uses Optimality Theory (OT; Prince & Smolensky 1993) to formalize a system that regulates these conflicts. Working within OT, Flemming postulates that phonological constraints are motivated by perceptual factors and evaluate contrasts between sounds, rather than individual sounds themselves. Constraints based on the distinctiveness of contrasts mark a sound depending on how perceptually different it is from sounds it contrasts with. Traditional markedness constraints, however, depend on the markedness of the individual sound and do not say anything about the system of contrasts (2004:235).

Flemming uses vowels to explain the idea of perceptual space within Dispersion Theory, according to which there should be a specified minimal auditory distance between contrasting forms within a given language. This minimal distance is enforced through a MINDIST constraint with the format Dimension:distance (2004:239). Perceptual distance is computed along the F1 and F2 dimension for vowels so that the closer the two vowels are in their F1, for instance, the less perceptually distinct they are. MINDIST constraints specify how different along the F1 or F2 dimension contrastive vowels need to be. The less distinct the contrast, the greater the violation (and the sooner in the tableau it happens), so MINDIST = D:n is ranked above MINDIST = D: n+1.
Flemming (2004: 246) uses a scale to illustrate the distance among F1 contrasts, which I
provide in example (16). Using this scale we can see that, for example, there is a more perceptually distinct F1 contrast between /a/ and /e/ than /a/ and /æ/, based on the perceptual distance between them.

\begin{center}
\begin{tabular}{cccccccc}
7 & 6 & 5 & 4 & 3 & 2 & 1 \\
/a/ & /æ/ & /ɛ/ & /e/ & /ɛ/ & /ɪ/ & /i/ \\
\end{tabular}
\end{center}

In order to maximize the number of contrasts Flemming proposes a MAXIMISE CONTRASTS constraint, which selects the largest viable inventory. The ranking of these constraints is language-dependent, more precisely the ranking of MAXIMISE CONTRASTS relative to the MINDIST constraints can vary from language to language, resulting in different vowel inventories. Flemming does not elaborate on the effort minimization constraints, so he proposes specific ones when needed (2004:242, but see e.g. Kirchner (2004) for a compatible approach to minimization of articulatory effort). The distinctiveness (MINDIST) constraints result in contrasting sounds spreading evenly over the auditory space as much as articulatory effort constraints allow. A result of the interaction of the constraints is neutralization of contrasts that are not distinct enough (2004:243). This goes along with Steriade’s (1995, 1997) idea that contrasts become neutralized in contexts where “the cues to the relevant contrast would be diminished or obtainable only at the cost of additional articulatory maneuvers” (Steriade 1997:1).

I am going to focus on how Flemming applies his Dispersion Theory to vowel contrasts, more precisely to the cases where the number of vocalic contrasts decreases in
unstressed syllables due to vowel raising. The author illustrates his analysis with southern Italian dialects (from Maiden 1995) that show a five vowel system in stressed syllables, /i, e, a, o, u/, but only a three vowel system in unstressed syllables, /i, a, u/, where the reduction results from neutralization of F1, i.e. height contrasts only (2004:244). The relevant examples that Flemming presents for this pattern are shown in table 5.

<table>
<thead>
<tr>
<th></th>
<th>Stressed vowels</th>
<th>Unstressed vowels</th>
</tr>
</thead>
<tbody>
<tr>
<td>[i]</td>
<td>vín:i</td>
<td>vín:imu</td>
</tr>
<tr>
<td>[e]</td>
<td>véni</td>
<td>vínimu</td>
</tr>
<tr>
<td>[a]</td>
<td>ávi</td>
<td>aviti</td>
</tr>
<tr>
<td>[o]</td>
<td>mórí</td>
<td>mürimu</td>
</tr>
<tr>
<td>[u]</td>
<td>ú:j:i</td>
<td>ú:j:imu</td>
</tr>
</tbody>
</table>

Table 5: Examples of the vowel pattern of Southern Italian dialects by Flemming (2004:244)

According to Flemming, this pattern results because in unstressed positions it is harder to make the distinctions in F1 contrasts. The author attributes this to durational differences between stressed and unstressed vowels in Italian. His analysis proposes that the reduced vowel duration in unstressed syllables makes it harder to produce lower vowels, which is the motivation for their raising, thus his analysis crucially relies on the fact that unstressed low vowels are in fact higher than their stressed counterparts. This raising leads to a smaller range within the vowel space for distinguishing F1 contrasts, which results in a smaller number of contrasts (2004:245). In order to support his theory, he cites a previous study on Swedish vowels (Lindblom 1963) which showed that F1 for non-high vowels decreased as vowel duration decreased. This same correlation between
decreased duration and vowel raising has been found in central Italian too. He also points out that there is more effort required and longer duration for low vowels, which has been reported in both impressionistic and experimental studies, such as the case of /a/ reduced to schwa in unstressed syllables in several languages. Flemming formalizes this analysis of vowel raising as resulting from the interaction of MINDIST with two markedness constraints, captured in the constraint ranking in example 17.

(17) UNSTRESSED VOWELS ARE SHORT, *SHORT LOW V, MINDIST = F1:2 >> MINDIST = F1:3 >> MAXIMISE F1 CONTRASTS

UNSTRESSED VOWELS ARE SHORT is a general markedness constraint that requires unstressed vowels to be shorter than stressed vowels. This constraint is always satisfied in this language and is therefore not included in the tableau below. *SHORT LOW V is a constraint that works against producing a short low vowel. Neither of these aforementioned constraints applies in stressed syllables. Next, in table 6, I present the tableau that shows how these constraints are used to describe unstressed vowels in Southern Italian.

<table>
<thead>
<tr>
<th></th>
<th>*SHORT LOW V</th>
<th>MINDIS T = F1:2</th>
<th>MINDIS T = F1:3</th>
<th>MAXIMISE F1 CONTRASTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>i-e-a</td>
<td>*!</td>
<td></td>
<td>✓✓✓</td>
</tr>
<tr>
<td>b)</td>
<td>i-ε-ɐ</td>
<td></td>
<td><em>!</em></td>
<td>✓✓✓</td>
</tr>
<tr>
<td>c)</td>
<td>ɐ-i-ɐ</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 6: Ranking of constraints in Optimality Theory tableau, adapted from Flemming (2004:247)
Candidate (a) is ruled out because it violates the top ranked constraint against short low vowels because it has a short vowel /a/. The distinctiveness constraints (MINDIST) are next and they both outrank the MAXIMISE CONTRASTS constraint. The ranking of MAXIMISE CONTRASTS below the distinctiveness constraints is crucial to determine the amount of F1 distinctiveness that the vowels need to display. This is determined by the MINDIST constraint that directly dominates MAXIMISE CONTRASTS, in this case F1:3. Candidate (b) violates the second distinctiveness constraint, for not having enough F1 distance between the vowels, refer back to the scale in (16), so candidate (c) is the optimal candidate. These rankings explain how the two-height vowel system is derived in Southern Italian and could be extended to other languages where vowel neutralization in height occurs in unstressed positions.

Flemming adds that in other languages, such as Brazilian Portuguese, reduction in the vowel system can also be attributed to durational differences of unstressed vowels, rather than by a different ranking of the MINDIST constraints. For instance, the post-tonic position is shorter than the pre-tonic position and for that reason there are different patterns of reduction in pre-tonic and post-tonic syllables. Thus, one explanation for the reduction to a three-vowel system in unstressed final syllables, and not in the pre-stress ones, in Brazilian Portuguese is based on the shortened duration in the post-tonic position, where it is more difficult to produce a lower vowel, compared to the pre-tonic or tonic positions, which leads to the production of only higher vowels. This is in contrast with unstressed pre-tonic syllables where there is a five-vowel system, and tonic syllables where there are seven vowels possible. Overall, Flemming shows that due to shortened
duration there is raising, and this results in a reduction in the number of contrasts, which affects vowel height in this case.

Another approach to vowel weakening is presented in Crosswhite (2004). The author proposes two different categories of vowel weakening\(^2\), those based on contrast enhancement and those based on prominence. This view opposes the commonly held idea that vowel weakening is one single process. The way in which the weakening is achieved, through different neutralizations, will vary among languages.

Weakening to enhance contrast means that certain perceptually difficult vowel qualities can only be expressed in the stressed position, i.e. they are less likely in unstressed syllables. Three vowels, \([i, u, a]\), are known as corner vowels since they are maximally dispersed from one another. Crosswhite proposes that they are the perfect vowels in positions where perception may be a problem, i.e. unstressed syllables, because these vowels have other special qualities including quantal effects, meaning that a wide range of articulations will produce these same quality vowels, and their formant frequencies make them easier to perceive than other vowels. The author provides examples from Belarusian where the mid vowels /e, o/ are lowered to [a], which results in only a three way distinction \([i, u, a]\) in unstressed syllables (2004:192). Since there is greater dispersion of the vowels, there is less acoustic confusion. Another example of weakening, through raising, has been attested in the Native American language Luiseño,

\(^2\) Crosswhite refers to these processes as reduction, but I have chosen to use the term weakening as a synonym for what she calls reduction.
where the mid vowels are raised to high vowels, resulting in only the three corner vowels in unstressed position. Using Optimality Theory, Crosswhite proposes a licensing constraint which captures the difficulty of perceiving the contrasts between vowels in unstressed positions (LIC-NONCORNER/STRESS: “non-corner vowels can only be licensed in stressed syllables”). We will now discuss the weakening through raising in Luiseño more thoroughly, since this process is the most similar to the vowel raising found in rural Michoacán. I present this discussion using the tableaux in table 7 where Crosswhite shows examples of weakening through raising using hypothetical words from Luiseño.

<table>
<thead>
<tr>
<th></th>
<th>LIC-NONCORNER</th>
<th>MAX [round]</th>
<th>MAX [+front]</th>
<th>MAX [-high]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. /toˈta/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) [tuˈta]</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>b) [taˈta]</td>
<td></td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) [toˈta]</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. /teˈta/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) [tiˈta]</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>e) [taˈta]</td>
<td></td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>f) [teˈta]</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Tableaux for hypothetical words from Luiseño, adapted from Crosswhite (2004:199)

In table 7 we see that the licensing constraint is undominated and the faithfulness constraints are ranked such that MAX[-high] is in the lowest ranked position. In Luiseño, candidates that contain lowered vowels are eliminated due to their violation of the MAX[round] or MAX[+front] constraints, which are ranked above MAX[-high]. For
both hypothetical words in Luiseño, the LIC-NONCORNER/STRESS constraint eliminates the option with the non-corner vowel in the unstressed position (candidates c and f). For the first form /toˈta/, the first faithfulness constraint $\text{MAX[round]}$ maintains the round quality of the vowel, thus eliminating candidate (b). For the second form /teˈta/, the faithfulness constraint to maintain the front quality of the vowel $\text{MAX[+front]}$ eliminates candidate (e). The violation of $\text{MAX[-high]}$ does not matter in the evaluation because the optimal candidate has already been chosen by the higher ranked constraints.

The other type of vowel weakening that Crosswhite describes is based on prominence reduction, where salient or more prominent vowel qualities are avoided in unstressed positions. This is determined by crossing two phonetic scales, an accentual prominence scale, where stressed syllables have more prominence than unstressed syllables, and a vocalic prominence scale, where the more sonorous vowels have more prominence. The author provides the example of Bulgarian, where /e, a, o/ are all reduced to vowels with lower sonority in the unstressed position resulting in a new vowel inventory of /i, ə, u/.

After elaborating on the two different types of weakening, Crosswhite indicates that cases where only the mid vowels /e, o/ are neutralized through raising to [i, u] in unstressed syllables and unstressed /a/ remains unaffected are a bit challenging to categorize. It is difficult to determine whether the mid vowels are becoming more contrastive or less prominent by changing to /i, u/, respectively, and there is no change of /a/ to give us an indication. This may lead us to wonder how we know that Luiseño is a case of contrast enhancement rather than a reduction in prominence. Crosswhite explains,
“... it could be that /a/ is immune because LIC-NONCORNER/STRESS does not affect unstressed /a/, or it could be the case that high rank of MAX[+low] blocks reduction of /a/” (2004: 221). The author hypothesizes that the former is true in the case of Luiseño, but it is not clear how she reaches that conclusion. It seems that Luiseño is not the best example to argue for two different motivations for weakening. Crosswhite points out many languages where both types of vowel weakening occur, such as dialects of Russian, Italian, and Bulgarian (2004:222). This will be interesting to consider for the current study since the vowel raising pattern appears to be similar, although /a/ has not yet been analyzed in the Colongo dialect.

The previous theories on vowel weakening propose several possible explanations for the raising of mid vowels to high vowels in unstressed positions and provide support for my Weakening Hypothesis. First of all, vowel raising has already been considered a weakening process in the literature, for example by Flemming (2004). Thus, in my Weakening Hypothesis, I propose that vowel raising in Colongo should be considered another type of vocalic weakening, alongside processes such as unstressed vowel devoicing (UVD). If we consider unstressed mid vowel raising as a weakening process, we would expect to see similarities in the linguistic factors that affect both vowel raising and UVD. For example, both unstressed vowel raising and UVD tend to occur in the same linguistic contexts, namely in post-tonic closed syllables, especially in utterance final position. Thus, this is an indication that this is a location where vowel weakening tends to occur in Mexico, where we have seen evidence of both processes (discussed in this chapter). The variable neutralization of the mid vowels /e, o/ with the high vowels /i,
u/, respectively, in vowel raising is further evidence of weakening in the form of reduction of vocalic contrasts. However, this reduction alone is not sufficient to consider this a weakening process, since /i, u/ are very uncommon in word-final position in Spanish. Thus, we must also consider weakened articulation, resulting in more coarticulation with surrounding sounds, and reduction in duration, an inherent quality of high vowels when compared to mid vowels cross-linguistically, as additional support for the idea that vowel raising should also be considered a weakening process. Note that UVD also involves a reduction in duration, sometimes to the point of elision, which could be the motivation for the process. After determining the factors that favor vowel raising, I hope to be able to provide more evidence to confirm my Weakening Hypothesis and characterize the nature of the vowel raising process in Colongo.

2.5 Social networks

Social networks became an increasingly popular methodological approach in sociolinguistic studies in the 1980s as there was less interest in broad social categories and more of an attempt to concentrate on smaller, local groups (see Milroy 1980, Cohen 1982, Mewett 1982, San Juan and Almeida 2005, among others). Social networks have been used to show how individuals align themselves into groups and that people within these groups show similar linguistic patterns. The grouping into networks can be especially useful in smaller or rural communities, such as Colongo, the community under study in this dissertation, where there are no clear divisions based on socioeconomic status or social class. Milroy and Gordon (2003:120) describe several advantages of using
social networks. For example, since the networks are determined by focusing on local practices, they give an indication of the social dynamic and help to explain variation between individual speakers. Another advantage is that the criteria for determining the networks can be adjusted to fit the community under study. I will now discuss several studies that have incorporated the use of social networks so that we can see the characteristics used to determine the formation of different networks. By reviewing how social networks have been defined in previous sociolinguistic studies, we can see the justification for the criteria used in the current study.

Milroy (1987) explains how network structure can be quantified and how the measurements used to define those networks can be adapted to fit different communities. “Indicators” of integration are used to create a numerical score. The higher the score, the more dense and multiplex the network. This kind of dense network is also sometimes referred to as a closed network, where the opposite is called an open network. In Milroy’s (1980) Belfast study, these indicators were kin, friendship, and work. Thus, if someone worked with someone that she is also friends with, these individuals were linked in more than one capacity, which indicates a more multiplex network. The author also used measures that could be determined based on the data collected in the field, rather than attitudes or subjective measures. Milroy found that the network ties of the participants provided an indication of which linguistic variables they would use. Additionally, participants with the strongest network ties were the most likely to maintain non-standard phonological forms. The author explains, “the difficulty is that the indicators of this integration which are capable of being treated quantitatively (to enable ... a comparison)
are likely to be culturally determined and to vary from one community to another” (Milroy 1987:106). What Milroy describes as a difficulty is actually beneficial because this flexibility allows the indicators of integration to be adapted according to the community being studied. An additional advantage of using social networks in a community such as Colongo is that they are a great tool for studying smaller groups in more detail, especially in communities where large-scale categories such as social class do not provide a clear indication of the differences between speakers.

Milroy and Gordon (2003) elaborate on the use of ties in social networks. The authors explain the connection between ties and social networks as follows, “...an individual’s social network is the aggregate of relationships contracted with others, a boundless web of ties which reaches out through social and geographical space linking many individuals, sometimes remotely” (Milroy and Gordon 2003:117). These ties can be first-order ties, which is a direct contact, or second-order ties, which is through an indirect contact. First-order ties can also be classified as strong, such as with family, or weak, as in the case of acquaintances. The more that individuals are connected in a variety of ways, through work, friendship, family, etc., the more multiplex and dense the network. These types of dense or closed networks tend to maintain local linguistic norms while networks with weaker ties, open networks, are more susceptible to language change. Thus, a network analysis helps us to explain why certain groups are more likely to maintain non-standard features whereas others may change the way they speak due to influences from outside of the community. This differentiation is useful to explain the variation in vowel raising in Colongo. Previous social network analyses suggest that
participants with less exposure to external influences, those in a closed social network, should have more use of the non-standard vowel raising feature and the participants in a more open social network should have less vowel raising.

Diez-Cansecos’s (1997) study in Cusco, Peru demonstrates how the indicators that Milroy (1980) used can be adapted to fit a particular community. More precisely, her dissertation examines how the use of the palatal lateral and assibilated /r/ in Peruvian Spanish can be explained using a combination of both network and attitudinal analyses. Since many of the participants of this study work in different places, even though their occupations may be similar, Diez-Canseco decided to modify the indicators of social network membership used by Milroy. The author uses three measures to determine network density: the number of ties to other members of the community, the number of multiple ties (which she considers as those who have ties in more than one realm, for example work and family), and whether or not they return to their rural community. Her findings confirm that non-standard features are more likely to be maintained in dense social networks. This study also provides an example of how social network indicators can be modified to better represent the social situation of the group under study. The current study will need to take into account the importance of utilizing indicators that will best represent the types of social networks in the community.

Bortoni-Ricardo (1985) conducts an analysis of weak network ties of rural speakers in Brazil. The author investigates the role of social networks in the spread of linguistic features, but unlike most studies on social networks, she does not focus on the preservation of non-standard linguistic features in closed networks, but rather on the
increase of use of standard features in networks with weak ties. Bortoni-Ricardo studies the use of several linguistic features, such as vocalization of the alveopalatal lateral and the reduction of final rising diphthongs, as characteristic of rural Brazilian speech. Both an integration index and an urbanization index were used to determine the different networks. The former was based on personal ties and the latter was composed of variables such as level of schooling and media exposure, among others. The author noted more variation in the use of the typically rural features and increased use of standard features as the rural participants integrated into the more urban society. Thus, as the participants’ networks became larger, the weak network ties created the opportunity to move away from what was considered the “norm” or characteristic of the speech in the rural area. The author’s focus is not on the adaptation of standard features typical of the urban environment, but rather the diffusion in the use of dialectal features as a result of the weakening social ties with the rural community. In other words, network ties are weakened as participant mobility increases, which leads to less use of non-standard features. This conclusion is relevant to the current study since many of the participants in Colongo migrate from their rural town to urban areas in the United States. Their mobility and more open network should be considered as variables that could have an effect on the amount of vowel raising in their speech.

Cashman (2003) determines the social networks of her informants based on their own explanation of their ties within the community. The two groups that are compared are immigrants to the United States and their children who were born in the United States. One of the variables in the study is whether or not bilingual speakers in Detroit,
Michigan tend to maintain their Spanish or switch to English based on the composition of their social networks. The author analyzes the social networks using four criteria: percentage of monolingual English speakers, percentage of monolingual Spanish speakers, percentage of bilingual (Spanish/English) speakers, and whether or not the speakers are Latino. The effect of each of these aspects of the social networks is compared. Cashman finds that none of the characteristics of the social network have an effect on the Spanish maintenance of the immigrant group. However, for the group born in the United States, a social network with more monolingual Spanish speakers and more Latinos has a positive correlation with maintenance of Spanish, and a social network with more monolingual English speakers has a negative correlation with their Spanish preservation. This study shows how an analysis of the make-up of social networks can give us an indication of the linguistic choices of individuals.

The examination of the previous studies has shown the flexibility of social networks and how they can be used in different types of communities, for example both monolingual and bilingual. Also, they have been employed in the study of a variety of languages including Spanish, English and Portuguese. In the case of rural Michoacán, social networks are the ideal method to capture the variation among individuals for several reasons. First of all, being as Colongo is such a small community, discussed in more detail in section 3.1.1, a large scale variable such as socioeconomic status would put everyone in the town in one category. By breaking down the community into social networks, we can capture the fine-grained differences among individuals. Secondly, the small nature of the town also makes using social ties nearly impossible since each
member of the community is tied to many others in a variety of ways and there are daily interactions among them. Therefore, the adaptability of the criteria for determining social networks will be beneficial as distinct factors that influence interactions within and outside of the community are used. Finally, this community is distinctive in that there is ample mobility, especially to and from the United States. Thus, those who leave the town are in contact with other dialects of Spanish and this factor could certainly affect the amount of vowel raising in a given individual’s speech. Social networks have proven to be a successful tool, especially in the study of smaller communities, and help to explain variation that may be based on the amount of outside influence to members of the community.

2.6 Conclusions

The previous review of vocalic processes in Spanish, vowel weakening theories, and social network methodologies helps to situate the current dissertation and provide evidence of the need for a systematic study of vowel raising in Mexican Spanish. My dissertation will contribute to dialectal descriptions of Michoacán Spanish and will include an extensive analysis of the linguistic and social factors that influence raising in this dialect. By performing an acoustic measurement of each vowel token, I provide a more precise account of the process, and can use those instrumental results to support my Weakening Hypothesis of vowel raising in Colongo. Finally, by incorporating the use of social networks, I capture smaller scale social differences which might otherwise be overlooked.
Chapter 3. Methodology

This chapter presents the methodology of a variationist study that aims to determine the linguistic and social factors that influence unstressed mid vowel raising in rural Michoacán, Mexico. The analysis is based on production data collected through recorded interviews and includes an acoustic analysis of the vowels and the grouping of participants into social networks. This study adds to the scarce literature on the occurrence of vowel raising in Mexico, and to the literature on Mexican Spanish in general, especially in small, rural communities such as Colongo. Section 3.1 offers an in-depth description of the data collection, including the region where it took place, the participants, and the tasks. In section 3.2, I give a description of the envelope of variation, i.e. which contexts were included and excluded in the data analysis. Section 3.3 explains the auditory and acoustic data analysis. Then, in section 3.4, I offer a detailed explanation of the dependent and independent variables that I analyze. Finally, in section 3.5, I present my initial hypotheses about which factors will be most influential on vowel raising in Colongo.

3.1 Data collection
Although I initially noticed this vowel raising feature through telephone conversations with members in the community of Colongo, it was not until I visited the area in December of 2010 that I realized how salient the feature really is. After getting the methodology approved by the Institutional Review Board (IRB) at The Ohio State University, I returned to Colongo in the summer of 2011 to perform a three-part study which included a sociolinguistic interview, a reading task and a picture task. Before an explanation of the data collection itself, I will first describe the area where my data was collected and give some biographical information about the participants.

3.1.1 Description of the region of study

The area where I conducted my research is called El Colongo, affectionately known as un ranchito ‘a little ranch’ by the people who live or once lived there. This is probably due to the rural nature of the town, where it would not be out of place to see a cow, horse, or some chickens crossing one’s path. The population of Colongo is approximately 700 people. In fact, during my first visit there was not even a sign announcing one’s arrival to Colongo. Within Mexico, Colongo is located in the state of Michoacán, which we can see along the western coast in the map of Mexico in figure 1. Within the state of Michoacán, Colongo is located in the northwest, within the municipality of Ixtlán de los Hervores, with the closest large city center being Zamora. It takes about 15 minutes to drive to Ixtlán de los Hervores and 30 minutes to reach

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3 Information obtained from: http://mexico.pueblosamericana.com/i/el-colongo/
Zamora. Figure 2 shows a partial map of Michoacán where I have circled Ixtlán de los Hervores and Zamora, and the arrow indicates Colongo.

Figure 1: Map of Mexico

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4 Image taken from: http://2.bp.blogspot.com/-IcC5tAdTiHA/UaZ19BKiybl/AAAAAAAAHIU/ABkWzpg3tBU/s1600/mexico+state+map.jpg
Colongo is a small, rural community whose economy is mainly based on agriculture. In this way, it is similar to the communities in Spain and Puerto Rico where vowel raising has been more extensively studied (Holmquist 1985, 1998, 2005 and Oliver Rajan 2007, 2008). Most of the men, and some women too, work in the fields outside of town. Many families also run small businesses out of their homes, such as selling some type of food (sweets, snacks, drinks, meals) or maintaining a small store. This can only be done by those who have access to transportation to Zamora to get supplies. The main plaza contains the town’s church, and both the plaza and the church had been recently

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5 Image taken from: [http://www.mexconnect.com/assets/0000/5647/mapmichoacanpdf.pdf](http://www.mexconnect.com/assets/0000/5647/mapmichoacanpdf.pdf)
renovated prior to my second visit. Despite the job opportunities mentioned, the community is dependent on money sent from family members in the United States. Especially because field work is not always available, depending on the season or weather conditions, the outside money is necessary to cover anything other than daily living expenses. Those who do not receive outside help have a noticeably lower standard of living and very few interactions outside of Colongo.

3.1.2 Participants

While a true random selection may be more representative of the general population under study, access to the speakers is not as easy to obtain. Additionally, since each person can be a complete stranger with no ties connecting him or her to the investigator, the interaction may be even more unnatural. Conversely, the “friend of a friend” method may not result in such a representative sample of the broader population, but there is more access to the participants and they are likely to feel more comfortable knowing that they have a friend or acquaintance in common with you. This method is also sometimes referred to as the “snowball” technique, where the researcher can fill a quota with a certain type of participants, for example male or over 50 years old, through the network of friends of other participants (Milroy and Gordon 2003). The “friend of a friend” method is also commonly used in the study of social networks, which is one of the methods I use to analyze the social factors, as I describe in detail in section 3.4.2.2. Milroy (2002) explains that in her work on social networks in Belfast she used this method to interview members of the same social group rather than isolated individuals. In
this way, “... she was able to obtain large amounts of spontaneous speech as well as relevant social and demographic information, and the effect of the observer was lessened” (Milroy 2002:553). This method of gaining access to participants also allows the researcher to become part of the social context and not approach the situation as a total outsider. The idea of a mutual friend creates a connection that would otherwise not be possible (Milroy and Gordon 2003). In reference to Milroy’s Belfast study, Milroy and Gordon (2003:75) explain, “As a consequence of the reciprocal rights and obligation that members of close-knit groups contract with each other, the mention of the insider’s name had the effect of guaranteeing the fieldworker’s good faith; moreover, members of the group appeared to feel some obligation to help her in her capacity as a friend of their friend, so that she acquired some of the rights as well as some of the obligations of an insider.” Thus, the “friend of a friend” method does have several advantages, including decreasing the effects of the observer and giving the researcher insights into the community, especially when combined with the study of social networks, as was seen by Holmquist (1998, 2005) and Oliver Rajan (2007, 2008).

Following previous work on social networks, I used the “friend of a friend” method for my study in Colongo. Because I had visited the area previously, I was not quite a stranger, but not an insider either. In a town that small, everyone notices when someone new has arrived, so at least people knew who I was even if they had not spoken to me directly. Other than the people I already knew from my previous visit, my mother-in-law helped me gather the rest of the participants, many of whom were excited to meet her son’s wife. This also helped to create a more casual conversation since we could talk
about him or their relatives in the United States. Recruiting informants in this way also gave me some insights into the structure of the social networks in Colongo. My goal was to get an equal number of females and males within a variety of age groups, from teenagers to the older generations. Overall, 32 informants ages 13 and older, 17 females and 15 males, took part in the study. At the end of section 3.4, I present a breakdown of the participants (table 10), including age, gender, and the social factors discussed in that section.

3.1.3 Task

The sociolinguistic interview is a common method of collecting speech samples for variationist studies. Labov (1984:32) discusses the goals and methods for guiding the conversation in a sociolinguistic interview. A few of his suggestions are to obtain recorded speech with demographic data, comparable responses to similar questions, narrations of personal experiences, and information on specific linguistic structures. Beginning the conversation with demographic information allows the participant to get comfortable with the recording situation while providing important information for the social aspects of the study. Labov recommends following a series of conversation modules, i.e. groups of questions about particular topics. In this way, the participants will be responding to similar types of questions. However, he warns that the interview should not only consist of a series of responses to questions by the interviewer. Labov summarizes his thoughts on this matter quite simply, “The sociolinguistic interview is considered a failure if the speaker does no more than answer questions” (1984:38). He
considers the shifts in conversation initiated by the speaker to be the most important parts
of the interview. It is during these tangents in the conversation that the speaker provides
personal narrations on experiences that he or she is most comfortable discussing.

With Labov’s discussion in mind, I designed a flexible conversation module to
conduct sociolinguistic interviews. After an initial general explanation of my interest in
the way that people speak in Colongo and receiving consent to record the conversation, I
began by collecting biographical information from each speaker. Then I asked a few
questions about topics such as school, work, celebrations, food, family, etc. in order to
encourage story telling. Although there was a structured pattern for the topics, like the
conversation modules Labov (1984) describes, the conversation followed whatever the
participant seemed most excited to talk about. Since the topics themselves were less
important than the actual speech production, the goal was to find a conversation topic that
kept the participant talking, with only occasional questions from the investigator if
needed to continue the conversation. This follows Labov’s idea that the tangents from the
investigator’s questions provide the most interesting responses.

All the interviews were recorded either in the house of my mother-in-law or the
house of my brother-in-law next door. My goal was to create a semi quiet environment

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6 After the interview, the participants were recorded while completing two other tasks to target the same
phenomenon: a picture task and a sentence reading task. Many of the participants could not or did not want
to participate in the last two tasks either because of vision problems or lack of confidence in identifying
pictures or reading. Since I did not have as many participants for these tasks, I decided to work exclusively
with the data from the sociolinguistic interviews. I hope to use the data from the other tasks for future
studies (after my dissertation).
where the participants would feel comfortable, as if they were just sitting on a neighbor’s
couch having a casual conversation. A digital voice recorder was used for the recording
of the interviews. After each interview I then transferred the recording from the memory
card to my personal computer. The end result was a series of 32 interviews ranging in
length from 15 minutes (due to a microphone malfunction) to 1 hour long, with the
average interview lasting approximately 30 minutes. However, due to the poor recording
quality of one interview, it was excluded from the analysis. In the end, I analyzed 31
recorded interviews.

3.2 Envelope of variation and exclusions

Most of the work on unstressed vowel raising (Holmquist 1998, 2005 and Oliver
Rajan 2007, 2008, to name a few) has focused on final unstressed mid vowels. Typically,
the examples of vowel raising involve two-syllable words with penultimate stress and an
open final syllable. Oliver Rajan (2008) uses potε ‘pot’, realized as [poti] or [pote], and
pelε ‘hair’, pronounced [pelu] or [pelo], to show examples of the variation in mid vowel
raising in the coffee zone of Puerto Rico. However, Oliver Rajan also found evidence of
mid vowel raising in closed syllables, articles and clitics, and in pre-tonic position. A few
of these examples are: despues [dihpweh] ‘after’, de agua [djaywa] ‘of water’, and el
saco ese [ilsakuesi] ‘that coat’ (Oliver Rajan 2008:202-204). The pre-tonic stress position
and one-syllable words do not appear to have been addressed in other studies of vowel
raising thus far. After an initial impressionistic analysis of my own recordings, I
determined that vowel raising in articles, stand-alone clitics, and in monosyllabic words
was virtually not found in this variety of Spanish. I only encountered a few examples of raising in those contexts, such as two instances of raising with the word \textit{m}e\textsubscript{\text{\textipa{[mi]}}} \textit{agarra} ‘he grabs me’ or \textit{m}i \textit{hacia} ‘she would do [something] to me’, and one with the word \textit{d}e\textsubscript{\text{\textipa{[di]}}} \textit{bote} [\text{\textipa{[di]}} \textit{agua} ‘water container’. Thus, given the almost non-existent presence of raising in this type of words, their unstressed vowels were not included. It should be further noted that the three previous examples with raising could be instances of hiatus resolution through diphthongization, since the monosyllabic words are followed by words that begin with a vowel, and therefore should not be included in the current data so as not to confound the vowel raising analysis. No examples of raising in pre-tonic position of non-monosyllabic words, for example \textit{p}e\textsubscript{\text{\textipa{[ej]}}}\text{\textipa{[o]}}\text{\textipa{[t]}}\text{\textipa{[a]}} ‘ball’, were found. As such, the vowels that were considered within the envelope of variation for the present study were all unstressed mid vowels after the tonic syllable and within the word. Monosyllabic words were excluded. However, there may be more than one vowel analyzed per word in longer words such as \textit{v}a\textsubscript{\text{\textipa{[ej]}}}\text{\textipa{[o]}}\text{\textipa{[n]}}\text{\textipa{[o]}} ‘let’s go’, where both instances of /o/ were examined for raising. Thus, the target vowel did not always occur in the final syllable.

Some exclusions were applied to the possible target vowels. Any time the target vowel was followed by another vowel, it was not included because it has also been shown that there are many possible hiatus resolution strategies, including diphthongization and elision, among others, when two vowels occur next to each other across words (Hernández 2009). Furthermore, there is the possibility of fusion of the two vowels. An example of this type of token is \textit{pe}\textsubscript{\text{\textipa{[ej]}}}\text{\textipa{[r]}}\text{\textipa{[o]}}\text{\textipa{[t]}} ‘but another’, which would be excluded, since both the target vowel and the following sound are /o/. So, in order to ensure that my
analysis is of the vowel raising process, and not interactions between the vowels themselves, cases of an unstressed vowel followed by another vowel were excluded. Additionally, target vowels that were devoiced or elided to the point that no formant measurements could be taken, known as unstressed vowel devoicing and discussed in section 2.3.1, were also excluded from the data. This acoustic determination is discussed more thoroughly in section 3.3.2. To summarize, the envelope of variation includes all post-tonic unstressed mid vowels in multi-syllabic words that are not directly followed by another vowel. In the next sections I present an explanation of the analysis of the vowels followed by a description of the dependent and independent variables.

3.3 Data analysis

The tokens taken from the recordings are the front and back post-tonic unstressed mid vowels, /e/ and /o/, given the envelope of variation discussed in section 3.2. The data was analyzed using both auditory and acoustic measurements and each token was coded for a variety of linguistic and social factors, as I will explain in section 3.4.2. For each interview I chose to start looking for tokens around the ten minute mark so that at that point in the interview the speaker had become more comfortable with me and the
recording situation. Approximately 150 tokens were collected for each of the 31 speakers, which resulted in a total of 4,586 total tokens analyzed.  

3.3.1 Auditory data analysis

Almost all of the previous studies on vowel raising, from the more basic descriptions (Boyd-Bowman 1960) to more thorough analyses of the factors involved (Holmquist 1998, 2005 and Oliver Rajan 2007, 2008), have relied on auditory, impressionistic analysis of the mid vowels. Although there is sometimes a distinction made between mid vowels, closed or raised mid vowels, and high vowels (Holmquist 1985, 1998), usually the investigator makes a decision of either raised or not based on auditory impressions. While the goal of this project is to extend the research on mid vowels beyond the auditory determination, I also performed an auditory analysis as part of the initial coding of the target vowels. Each of the tokens analyzed was judged by the investigator to be either raised or not raised. Many times the vowels had to be heard several times before making a decision. Any vowels that seemed to have the slightest raising were deemed raised. In addition to this binary auditory distinction, a continuous acoustic analysis was also performed.

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7 For three speakers, I was unable to reach 150 tokens either because of a malfunction with the recording device or because the speaker simply did not talk enough. The token count ranged from 115-142 for these speakers.
3.3.2 Acoustic data analysis

Acoustic evidence is important to support the auditory analysis of the mid vowels and, to my knowledge, this study is the first one on unstressed vowel raising in Mexico to perform an acoustic analysis of each vowel token. Oliver Rajan (2008) did conduct some acoustic analysis of the mid vowels from a few of her interviews from Puerto Rico, but this phonetic analysis was not performed on all of her tokens. A more recent study on vowel raising, Barnes (2013), expanded on previous vowel raising methodology and performed an acoustic analysis of each vowel token from the recordings with her participants. In order to present a more thorough analysis, I incorporate into my methodology the idea of going beyond auditory analyses and analyze each vowel token acoustically.

In the acoustic analysis of the vowels I used the measurements of the first two formants, F1 and F2. For this study, I used the software program Praat (Boersma and Weenink 2013) in order to obtain those measurements. After loading each recording into Praat, I began by isolating the words that had an unstressed mid vowel after the tonic syllable. Next, within the word I marked the beginning and end of the vowel. We can see this in figure 3 where the post-tonic vowel /o/ of *pongə* ‘I put’ is highlighted. Once I had
marked the beginning and end points of the vowel, I took the F1 and F2 values at the middle point.  

![Spectrogram of the word pongo ‘I put’](image)

Figure 3: Spectrogram of the word *pongo* ‘I put’

By using the formant values from the center of the vowel, it is less likely that there will be influence of the transitions to and from the surrounding sounds due to coarticulation. The measurements obtained from Praat were in hertz. However, in order to account for anatomical differences in the vocal tract among speakers of varying age and gender, and to be able to compare these values, I normalized the formant values of the vowels by

... 

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8 Due to the nature of the recording environment (in a home rather than a recording studio), in some cases the point of the vowel which Praat chose to be the center had an unusual rise or fall that did not correspond with the rest of the center region in the vowel. This could be due to background noise or just Praat improperly indicating the formants. In these cases, I moved the cursor a little to the left or right to correspond to what I deemed to be the true formant values for that vowel.
converting them to the ERB scale\(^9\) (Traunmüller 1997). I then used the normalized ERB values for F1 and F2 of each token to create two continuous variables.

As was discussed in the review of previous literature, section 2.3.1.1, unstressed vowel devoicing is frequent in Mexican Spanish and this feature is quite salient to speakers of other dialects. This was taken into consideration for the current analysis, since devoiced vowel tokens may have a weakened formant structure or be completely acoustically deleted. Keeping this in mind, I looked at the formant structure before including each token in my analysis. Target vowels that appeared to be devoiced, because I was unable to clearly identify the formants or the vowel was not visible in the spectrogram, were excluded. We see an example of this devoicing and lack of formant structure in the /o/ of *dinero* ‘money’ as shown in figure 4.

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\(^9\) The ERB (equivalent rectangular bandwidth) scale is a way to represent the acoustic measurements, i.e. Hertz, as auditory values, i.e. Bark. I chose to use this method because I am only interested in the first two formant values and do not include measurements for F0, F3, etc., which I would need if I were to define the entire vowel space.
3.4 The variables

In this section I will discuss both the dependent and independent variables that are the focus of this investigation of vowel raising in rural Michoacán. Previous studies, mentioned in section 2.3.5, have shown that vowel raising in other dialects of Spanish is influenced by both linguistic and social factors. Therefore, I will incorporate those and other additional factors into my analysis in order to see whether or not similar factors affect vowel raising in Colongo. First I will present the dependent variables followed by the independent variables.

3.4.1 The dependent variables

The front mid vowel /e/ and the back mid vowel /o/ were analyzed separately in this study. Even before recording the sociolinguistic interviews, it was quite clear,
because of its salience, that there was more /e/ raising than /o/ raising which suggests that these two vowels need to be analyzed independently of each other. Both Holmquist (1985, 1998, 2005) and Oliver Rajan (2007, 2008) considered the raising of the front mid vowel and the back mid vowel separately, and in the case of the latter, together as well, in their analyses. Thus, I decided to also analyze /e/ and /o/ as two distinct vowel raising processes.

There are six dependent variables that are included in this study. The first is the raised or non-raised distinction\(^{10}\), which is a categorical variable. The F1 and F2 values are the second and third dependent variables and they are continuous variables. Thus, each mid vowel has three dependent variables, which results in three different analyses of each vowel (/e/ and /o/), and a total of six dependent variables.

3.4.2 The independent variables

In the next few sections I will provide a thorough description of each of the independent variables, starting with the linguistic variables and then the social variables. I have also created separate summary charts of the linguistic and social independent variables after their respective sections as a quick reference.

\(^{10}\) We will see in chapter 4 that I ultimately decided to use a Discriminant Analysis of Principal Components (DAPC) to make this distinction, rather than using the auditory classification. I elaborate on both the DAPC process and the reason for using it in section 4.1.1.
3.4.2.1 Independent linguistic variables

In this section I will give a detailed account of the linguistic variables that were taken into consideration for each mid vowel token. Based on the factors that were found to be influential on vowel raising in previous research, the following variables were coded for: type of syllable, previous vowel, tonic vowel, previous consonant, distance (in syllables) away from the tonic syllable, number of syllables in the word, following sound, stress pattern, lexical category, position of the vowel within the word, whether the vowel occurs in a clitic, and word location within the utterance. I will now discuss each of these variables individually.

3.4.2.1.1 Type of syllable

Many of the previously mentioned studies on vowel raising do not discuss whether the syllable where the raising occurs is open or closed, although most of the examples provided are in open syllables. Oliver Rajan (2008), however, finds evidence that vowel raising occurs in closed syllables as well as in open syllables. Furthermore, examining the effect of open vs. closed syllables will allow me to compare vowel raising to other types of weakening, i.e. unstressed vowel devoicing. Thus, in my study each token was coded for either open or closed syllable. For example, the vowel /e/ in dics ‘you say’ is in a closed syllable and the vowel /o/ in otrọ ‘other’ is in an open syllable.
3.4.2.1.2 Previous vowel and Tonic vowel

The quality of the previous vowel has been shown to influence vowel raising in previous research (Navarro Tomás 1948, Holmquist 1998, Oliver Rajan 2008, among others). Researchers have also shown that a previous tonic syllable with a high vowel or high glide triggers more vowel raising than other tonic vowels in two-syllable words. However, if we consider words with more than two syllables and antepenultimate stress, such as vámonos ‘let’s go’, then we must pull these two variables apart and analyze them separately, since the previous vowel and tonic one might not necessarily be the same. Therefore, I created one category where I coded the quality of the previous vowel and another category for the quality of the tonic vowel. With the high frequency of two-syllable words in Spanish, in many cases the coding result from these two categories will refer to the same vowel. For example, in díces ‘you say’, both the previous and tonic vowel are /i/. However, in vámonos ‘let’s go’, the last /o/ has a previous vowel /o/ and tonic vowel /a/. It is precisely this difference that I am trying to capture. Therefore, in the statistical analysis, I use the previous vowel and tonic vowel as two separate independent variables. When analyzing all the data, I either include the previous vowel or tonic vowel category, whichever is more statistically significant for raising (see section 4.3). In both categories, I coded the actual vowel (/a, e, i, o, u/) and included diphthongs when present. For example, in vieng ‘he/she comes’ the previous and tonic vowels were coded as /je/. In this way I will be able to determine if there are different results for vowels and glides.
3.4.2.1.3 Previous consonant

The preceding consonant has also been found to have an effect on mid vowel raising. Navarro Tomás (1948) and Holmquist (1998, 2005) found that a preceding palatal is the environment that most favors the raising of the mid vowel. Oliver Rajan (2008) looked at the onset, based on articulation, and found that unstressed mid vowels in syllables with an elided onset (such as *baila(d)♂* ‘(have) danced’, where the /d/ is deleted) are the most likely to raise. Based on these previous findings, I coded for the preceding consonant, including the possibility of a deleted one. For example, in *dice* ‘she/he says’ I coded the previous consonant as /s/ and in *otro* ‘other’ I coded it as the complex onset /tr/. If there was no previous consonant, i.e. the target vowel was part of a hiatus, that was also part of the coding (as none), as in *feo* ‘ugly’. I also accounted for elided consonants, such as the /d/ in *fija(d)♂* ‘(have) noticed’, by coding them as deleted.

3.4.2.1.4 Distance (in syllables) away from the tonic syllable

By noting the number of syllables between the target vowel and the tonic syllable I am able to determine if more distance from the stress increases or decreases the chances of raising. This coding captures the difference between two-syllable words and those with three or more syllables, and it will give an insight into the patterns of raising for longer words. When the tonic syllable was right next to the target vowel I coded this as a 1, since it is one syllable away, for example, *dices* ‘you say’. When there was a syllable in between the tonic syllable and the target vowel I coded this as a 2, and so on. For
example, the last /o/ in vámonos ‘let’s go’ was coded as two syllables away from the tonic syllable.

3.4.2.1.5 Number of syllables in the word

Oliver Rajan (2008) found that the front mid vowel was most likely to be raised in three syllable words and the back mid vowel in four syllable words. In her data, words with four syllables had more vowel raising than words with all other numbers of syllables (2-6) when the mid vowels were combined. She also found significant differences in raising for front and back mid vowels in words with three (nosotros ‘we’), four (sacrificio ‘sacrifice’), or five (dedicábamos ‘we used to dedicate’) syllables. The number of syllables in the word was also coded for in the present study, where dices ‘you say’ was coded as a two and platiquemos ‘we talk’ was coded as a four.

3.4.2.1.6 Following sound

While the previous vowel and consonant have been shown to play a significant role in vowel raising, previous studies typically do not take into account the following sound. Although, recently, Barnes (2013) found the following segment to be a significant predictor of raising in her study on vowel raising in the Spanish of Spain in contact with Asturian. Studies on unstressed vowel devoicing (UVD) have found that this phenomenon is conditioned by the following sounds as it tends to occur more in syllables that end in /s/ or another voiceless consonant or in word-final position (Delforge 2008a, among others). Since I hypothesize that vowel raising and UVD are related, as far as both
are instances of vocalic weakening, I examine whether the following sound affects vowel raising as well. In this category, I coded the consonant or pause directly following the target vowel. When the token was in an open syllable, the following sound came from the next word, or pause if it was in word-final position. Thus, in (18), the following sound after the token /o/ was coded as the sound /k/ and in (19) the sound after /o/ was coded as a pause.

(18)  ...tengo que... ‘...I have to...’ (P22)

(19)  ...hijo mí [pause] ‘...son of mine’ [pause] (P22)

3.4.2.1.7 Stress pattern

Oliver Rajan (2008) found that most vowel raising occurred in words with antepenultimate stress, such as último ‘last’. Therefore, I coded for the stress pattern as well, distinguishing between penultimate and antepenultimate stress. There were no tokens with stress before the antepenultimate syllable and, as mentioned in the envelope of variation (section 3.2), tokens with final stress were excluded since only cases of mid vowels after the tonic syllable are being studied. Most of the tokens had penultimate stress, for example dices ‘you say’ and pero ‘but’. A few examples of tokens with

11 Each of my participants was given an identifying number to keep his/her identity anonymous. Here, for example, I am referring to participant (P) 22.
antepenultimate stress are andábamos ‘we used to walk/go’ and trabajábamos ‘we used to work’.

3.4.2.1.8 Lexical category

Holmquist (1998) and Oliver Rajan (2008) found different results for the effect of lexical category on vowel raising. Holmquist found that the unstressed mid vowels in nouns and verbs were most likely to be raised, although we do not know whether or not frequency was taken into account. Oliver Rajan did not find a significant difference in grammatical category for front and back mid vowels, except for verbs and adjectives where back vowel raising was favored. When front and back mid vowels were combined, raising was most likely in adverbs, then adjectives and nouns. In the present study, I coded each token as noun, verb, adjective, adverb, preposition, conjunction, pronoun, determiner, etc. in order to analyze any possible effects of the lexical category of the word containing the target vowel.

3.4.2.1.9 Position of the vowel within the word

Although the majority of the research on vowel raising focuses on word final position, Oliver Rajan (2008) provides evidence that raising is also possible in non-final positions. Therefore, I also coded for the position of the vowel within the word, differentiating between the two options of final (dice ‘she/he says’) and non-final (Ángeles ‘Angels’) position. The majority of my tokens do occur in word final position, but I am interested in determining whether the tokens in the non-final position have
raising patterns that are statistically different. Moreover, this category captures the difference between tokens that are the same number of syllables away from the tonic vowel, but occupy different positions within the respective words. For example, the target vowels highlighted here in *dice* ‘he/she says’ and *vámanos* ‘let’s go’ are both one syllable away from the tonic vowel, but the former is in word-final position and the latter is within the word. This difference in position may prove to be a significant factor.

3.4.2.1.10 Clitic or non-clitic

My own intuitions suggested that there may be more raising in clitics, only those that are attached to another word (see section 3.2), than non-clitics. The idea that vowel raising can occur in clitics is supported by Oliver Rajan’s findings in Puerto Rican Spanish, i.e. *guayándolos* ‘shedding them’ (2008:210), where we see raising of the direct object pronoun. Thus, I coded vowels that were in a clitic as such, and all others were coded as non-clitic. For example, the following tokens were both coded as occurring in a clitic; *bañarme* ‘to wash myself’ and *bañarnos* ‘to wash ourselves’.

3.4.2.1.11 Word location within the utterance

The last factor I considered was where the word was located in relation to the utterance. As I mentioned above, UVD has been shown to occur more frequently in utterance final position (Delforge 2008a) and if vowel raising is indeed another form of vowel weakening, then it is possible that it is more likely in the same position. Therefore,
I coded tokens as either within an utterance or in utterance final position. The most frequent position was within the utterance, as in (20):

(20) “...siempre me andaban emprestando las amigas...” (P30)
‘my friends were always loaning me [things]’

Tokens that were considered to be in utterance final position were at the end of the expression or thought, and were typically determined by the occurrence of a falling pitch pattern, as in (21):

(21) “...normalmente vengo el día sábado y me voy hasta el día de hoy, el lunes.”
(P1)
‘...normally I come on Saturday and do not leave until today, Monday’.

3.4.2.1.12 Summary of the independent linguistic variables

I have summarized the independent linguistic variables, including the different levels for each, in table 8:
<table>
<thead>
<tr>
<th>Variables</th>
<th>Levels</th>
<th>Selected examples</th>
<th>Translation of examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of syllable</td>
<td>open</td>
<td>vino</td>
<td>‘wine’ or ‘she/he came’</td>
</tr>
<tr>
<td></td>
<td>closed</td>
<td>ellas</td>
<td>‘they’</td>
</tr>
<tr>
<td>Previous vowel</td>
<td>/a/, /e/, /i/, /o/, /aɪ/, /aʊ/, /æ/, /i:/</td>
<td>cuándo: /wa/</td>
<td>‘when’</td>
</tr>
<tr>
<td></td>
<td>/æ/, /ɪ/</td>
<td>tiempo: /t/</td>
<td>‘he/she has’</td>
</tr>
<tr>
<td></td>
<td>/eɪ/, /ɪə/</td>
<td>teléfono: /o/</td>
<td>‘telephone’</td>
</tr>
<tr>
<td>Tonic vowel</td>
<td>/a/, /e/, /i/, /o/, /aɪ/, /aʊ/, /æ/, /i:/</td>
<td>vienen: /je/</td>
<td>‘you come’</td>
</tr>
<tr>
<td></td>
<td>/æ/, /ɪ/</td>
<td>iban(tes): /ɪ/</td>
<td>‘we were going’</td>
</tr>
<tr>
<td></td>
<td>/i:/</td>
<td>grande: /a/</td>
<td>‘big’</td>
</tr>
<tr>
<td>Previous consonant</td>
<td>none</td>
<td>feo</td>
<td>‘ugly’</td>
</tr>
<tr>
<td></td>
<td>deleted</td>
<td>novio</td>
<td>‘boyfriend’</td>
</tr>
<tr>
<td>Distance (in syllables)</td>
<td>1</td>
<td>nombre</td>
<td>‘name’</td>
</tr>
<tr>
<td>Number of syllables in word</td>
<td>2</td>
<td>pideme</td>
<td>‘ask me’</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>este</td>
<td>‘this’</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>compraron</td>
<td>‘they bought’</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>cobertores</td>
<td>‘blankets’</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>felicidad</td>
<td>‘congratulations’</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>originalmente</td>
<td>‘originally’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>obligatorio(mente)</td>
<td>‘obligatorily’</td>
</tr>
<tr>
<td>Following sound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>gentí también: /l/</td>
<td>‘people too’</td>
</tr>
<tr>
<td>Stress pattern</td>
<td>antepenultimate</td>
<td>sábado</td>
<td>‘Saturday’</td>
</tr>
<tr>
<td></td>
<td>penultimate</td>
<td>quince</td>
<td>‘fifteen’</td>
</tr>
<tr>
<td></td>
<td>adjective</td>
<td>grande</td>
<td>‘big’</td>
</tr>
<tr>
<td></td>
<td>adverb</td>
<td>cuándo</td>
<td>‘when’</td>
</tr>
<tr>
<td></td>
<td>clitic</td>
<td>mantenerl(ás)</td>
<td>‘maintain them’</td>
</tr>
<tr>
<td></td>
<td>conjunction</td>
<td>pero</td>
<td>‘but’</td>
</tr>
<tr>
<td></td>
<td>determiner</td>
<td>ese mismo</td>
<td>‘that same (one)’</td>
</tr>
<tr>
<td></td>
<td>interjection</td>
<td>este</td>
<td>‘ummm’</td>
</tr>
<tr>
<td></td>
<td>noun</td>
<td>sillones</td>
<td>‘armchairs’</td>
</tr>
<tr>
<td></td>
<td>preposition</td>
<td>desde</td>
<td>‘since’</td>
</tr>
<tr>
<td></td>
<td>pronoun</td>
<td>uno</td>
<td>‘one/someone’</td>
</tr>
<tr>
<td></td>
<td>verb</td>
<td>trajeren</td>
<td>‘they brought’</td>
</tr>
<tr>
<td>Lexical category</td>
<td>within utterance</td>
<td>“…cuándo vienen mis hijos…”</td>
<td>‘when my children come’</td>
</tr>
<tr>
<td></td>
<td>utterance final</td>
<td>“Comen puro pescado.”</td>
<td>‘They eat only fish’</td>
</tr>
<tr>
<td>Word location within utterance</td>
<td>final</td>
<td>otro</td>
<td>‘other’</td>
</tr>
<tr>
<td></td>
<td>non-final</td>
<td>miércoles</td>
<td>‘Wednesday’</td>
</tr>
<tr>
<td>Position of the vowel in word</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>clitic</td>
<td>cargándon(es)</td>
<td>‘carrying us’</td>
</tr>
<tr>
<td></td>
<td>non-clitic</td>
<td>mole</td>
<td>‘traditional Mexican sauce’</td>
</tr>
</tbody>
</table>

Table 8: Summary of independent linguistic variables
3.4.2.2 Independent social variables

In this section I will describe the social variables that were considered for each speaker. Based on the factors that were found to be influential on vowel raising in the previous research summarized in chapter 2, the following variables were coded for: age, gender, education, employment, and mobility, which I determine using time spent in and away from the community. Age, education, employment, and mobility were used to create the social networks, which I discuss at the end of this section, and were not considered independently in the analyses. Thus, gender and social networks were the two social variables that were included in the statistical analyses. I first explain the factors that were used to create the social networks and then I discuss the determination of the social networks themselves. I present a summary of all of the social factors in relation to my participants in table 10 at the end of section 3.4.

3.4.2.2.1 Social networks

As I mentioned above, education, employment, mobility, and age were factors that were considered in the creation of the social networks. Apart from age, which is used in the calculation of mobility, I will discuss the importance of each of these factors individually and the measure for including each one in the social network determination. Then, I provide a detailed description how the social networks were created for the Colongo community.
Education

The educational opportunities in Colongo are fairly limited. There is a primary school in the community, *primaria*, but in order to continue with their education, individuals must commute to neighboring towns. Depending on which secondary school, *secundaria*, they attend, students can walk, bike, or take a bus. The next level of schooling, *preparatoria*, is pre-university coursework and the location is even further from the town. There are several universities located in Zamora, which is approximately 30 minutes away from Colongo by car. Most of my participants have completed primary school and a much smaller number have completed or are currently in secondary school. I include the actual number of years of schooling in the education variable, which ranges from zero to nine. Note that the education variable was used in the creation of the social networks and not considered independently in the statistical analyses.

Employment

There are several employment options for people living in Colongo. The main source of income in the community is based on farming. The majority of the men, and some women, are hired as daily workers to go pick crops from the fields. One of the main crops that is harvested in this region is strawberries. Therefore, when asked about their occupation, many of my participants replied, “*Trabajo en la fresa*” ‘I work picking strawberries’. A truck comes by the town early in the morning daily to pick up the workers and bring them to the strawberry fields, which are located nearby, 10-15 minutes
away. Many of the people who do not work in the fields sell items from their homes, either in the form of a small convenience store, or homemade food items such as tamales ‘corn-based dough filled with meat and steamed in a corn husk’, fruit with picante ‘spicy chile powder’, or fresh juices. Some sell these items directly from their homes and others take their prepared foods and sell them in neighboring towns as well. The last option is to find work in a larger city, typically Zamora. Several women work as housekeepers or nannies for families in Zamora. They take a 30 minute bus ride into the city each morning and return in the evening each day during the week. This last employment option gives the community members a chance to interact with another dialect of Spanish that is less likely to exhibit the non-standard raising feature. Based on the employment options in the community, I created three levels for the employment variable: work from home (1), work in the fields (2), and work in Zamora (3). Children and others who do not work also belong to the work from home group. The three groups are assigned a numerical point value as indicated in the parentheses. Note that employment was considered in the creation of the social networks and not analyzed independently in the statistical analyses.

Mobility

I use the term mobility to describe the time spent in and away from the community. Using a categorization that is similar to Oliver Rajan (2007), I made a distinction between the participants who had never been out of the community and those that had. Typically, when individuals leave the community, this means that they go to the United States to work and send money back to their family. Travel to the U.S. means
exposure to English and other dialects of Spanish, either from other regions of Mexico or other countries, which may have an impact on their pronunciation. This exposure may have social implications as well as the individuals may possibly become more aware that their use of vowel raising is a non-standard feature.

To account for these differences in mobility, I used two different mobility scores, one based on the time away from Colongo and the other on the time back in Colongo. The participants received a zero for the time away score if they had never left Colongo. For the participants who had been out of the Colongo community, in order to be able to compare individuals of varying ages in a similar manner, I calculated the time out score by using the total number of years spent outside of Colongo divided by that participant’s age. What this really captures is the percentage of an individual’s life that was spent outside of Colongo. In this way, we have a method of comparing an 84 year old (P24) and a 28 year old (P18) while accounting for the possibility that the former could have spent much more time outside of the community since he is older. In this measurement of time spent outside of the community, a larger number indicates a greater percentage of time spent out of Colongo. The second score was calculated by dividing the number of years back in Colongo, since the last time the person returned to the community, by the age of the individual. This number was made a negative number to account for the reintegration into the community by reducing the overall mobility score. In this measurement of the time back in the community, a smaller number represents less time back in the community and a larger number represents more time back in Colongo.
two mobility scores, were combined with education and employment scores to create the social networks, which I discuss next, and not as their own independent factors.12

Social network

Although Colongo is a small, rural community, I noticed that there are differences in raising based on social factors. However, many of these social factors are correlated. For instance, the majority of participants who have left the community are older men with primary school education or less. The younger generation of boys is in or has completed secondary school and has never left the community. Additionally, the older generations generally have less education than the younger generation, more women than men work from home, and men have spent longer periods of time outside of Colongo than the women.

Based on the demographic information provided by the participants, I divided the community into social networks. By using social networks I am able to capture more fine-grained differences between participants that might be overlooked by only using large scale variables such as education, occupation, and socioeconomic status. Many of these larger scale variables do not capture the differences between individuals or groups in Colongo since the range of differences between education levels, types of occupation, and socioeconomic status is not very large. Furthermore, using social networks works

12 I also analyzed mobility by itself in the statistical models by combining the time away and the time back scores into a single independent variable. Neither as a continuous nor a binary independent variable, in separate analyses, did mobility alone turn out to be significant.
around the correlation between the social factors as mentioned above. In many of the previous studies that use social networks, see section 2.5 for a detailed discussion, the determination of the networks is based on ties between speakers in the community. In Colongo, however, the ties between the members of the community are dense and multiplex. This means that individuals interact with each other on many levels, i.e. as family or friends, in church, and/or in a business relationship (buying food or goods from others). Because there are so many ties between these individuals, I follow Holmquist (1998) and create social networks based on social variables. I created an index where I assigned point values to the four possible components of the social network determination: 1) education, 2) employment, 3) mobility score for time in Colongo, and 4) mobility score for time out of Colongo, when applicable. The determination of those point values is detailed in the description of each of those factors above. The score for each individual was calculated by adding the point values for each category and then dividing by the number of categories. The participants who had never left the community did not receive a score for the fourth category, so their score was divided by three. Those who had left the community had their scores divided by four. To summarize the point system described in the previous sections, fewer points were given for contexts that suggested less interaction with others outside of the community, and more points for the factors that gave the members more access to people outside of Colongo. As much as possible, I tried to use a continuous analysis rather than creating artificial categories for the social factors included in the network creation. The end result was a continuous numerical range for the social network score.
In table 9, I present the calculation of the social network score for two speakers as an illustrative example. Participant 10 (P10) has two years of schooling and therefore receives a two in the education component. He works in the fields outside of Colongo, so he receives a two for employment. He is 35 years old and has spent a total of 13 years away from Colongo. Thus, his time away score is 37.14, the number of years spent away divided by his age (13/35). It has been four years since the last time he returned, so his time back score is -0.11, which is the number of years away, divided by his age, and made a negative number –(4/35). By adding the four scores together and dividing by four, we can calculate his network score of 10.26 (41.03/4). Participant 25 (P25) has six years of education, and receives a six for the education score. She works selling products out of her home, so she receives a one for employment. She has spent no time away from Colongo, and therefore the category for time back is not applicable, so her time away score is a zero. By adding the three scores together and diving by three, we get the calculation of her social network score of 2.33 (7/3). All the other scores of the speakers were calculated in the same manner. We can see a comparison of the continuous network numerical range for all the participants in figure 5, where each circle represents an individual speaker. The distribution of the data shows that the majority of the participants have lower index numbers, similar to what we just saw for participant 25.

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Education</th>
<th>Employment</th>
<th>Time away</th>
<th>Time back</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>P10</td>
<td>2</td>
<td>2</td>
<td>37.14</td>
<td>-0.11</td>
<td>10.26</td>
</tr>
<tr>
<td>P25</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>n/a</td>
<td>2.33</td>
</tr>
</tbody>
</table>

Table 9: Example of social network score calculation
Based on the distribution of the participants using the continuous social network index, I also created a binary distinction in the social network analysis. Speakers whose network index was five or less were grouped into the closed social network and those

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13 I ran the statistical models with social network as a continuous variable and it did not have a significant effect on vowel raising for any of the dependent variables. Because of this I decided to work instead with the binary distinction.
with a score of more than five were grouped into the open social network. Five was chosen as the cut-off point because visually determined that this is where there was a change in speaker scores, i.e. those to the left of the line are similar and the change in the pattern starts after the continuous network index of five. This division is indicated in figure 5 with the vertical line. A lower network score was associated with a closed social network and a higher score with an open social network. A closed social network typically refers to a social situation where the members of the community have less access to people outside of the community (Milroy 2002). Alternatively, in an open network the members have more outside influence through interactions with members of other communities. If we refer back to table 9, we see that participant 10 is assigned to the open network and participant 25 belongs to the closed network. The binary distinction in social networks, open or closed, is used in the statistical analyses. In the case of Colongo, the difference in network is more of an indication of interactions with people from within or outside of the community. The closed network indicates more interaction with people within Colongo while the open network indicates the possibility of interaction with other dialects of Spanish.

3.4.2.2.2 Summary of the independent social variables

To summarize the independent social factors discussed in this section, I present table 10 where we see an overview of the social factors by participant. For the mobility column we see the time, in number of years, spent outside of Colongo, and for those who have been out of the community, the time, in years, back in the community. We also see
the social network assignment. Although I am including the individual factors that help determine the social network score, remember that gender and social network were the only two social variables included in the statistical analyses.
<table>
<thead>
<tr>
<th>Speaker</th>
<th>Gender</th>
<th>Age</th>
<th>Mobility</th>
<th>Education</th>
<th>Employment</th>
<th>Social network</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time out/Time back</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>F</td>
<td>23</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>18</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>20</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>closed</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>14</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>5(^{14})</td>
<td>F</td>
<td>16</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>17</td>
<td>0</td>
<td>9</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>60</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>closed</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>48</td>
<td>2</td>
<td>29</td>
<td>3</td>
<td>closed</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>31</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>35</td>
<td>13</td>
<td>4</td>
<td>2</td>
<td>open</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>14</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>closed</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>20</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>18</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>closed</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>20</td>
<td>0</td>
<td>7</td>
<td>3</td>
<td>closed</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>14</td>
<td>0</td>
<td>9</td>
<td>2</td>
<td>closed</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>48</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>closed</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>48</td>
<td>15</td>
<td>12</td>
<td>5</td>
<td>open</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>28</td>
<td>6</td>
<td>5</td>
<td>0</td>
<td>open</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>13</td>
<td>0</td>
<td>7</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>13</td>
<td>0</td>
<td>7</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>21</td>
<td>M</td>
<td>14</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>closed</td>
</tr>
<tr>
<td>22</td>
<td>F</td>
<td>79</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>closed</td>
</tr>
<tr>
<td>23</td>
<td>M</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>closed</td>
</tr>
</tbody>
</table>

Continued

Table 10: Summary of participants and social factors

\(^{14}\) Participant number 5 was excluded from the analysis due to poor recording quality.
3.5 Initial hypotheses

To conclude this chapter I present a summary of my initial hypotheses regarding the expected results from the data analysis.

- Although previous studies of other dialects of Spanish with vowel raising report that there is more raising of the back mid vowel, /o/, I expect to find more raising of the front mid vowel, /e/. Beginning with my first telephone conversations with members of the Colongo community, the raising of /e/ was the most salient feature. I believe my results will confirm my initial observations.
I anticipate that there will be more raising overall in closed syllables since vowel weakening is typically found in this position in the form of devoicing, in Mexico and in other varieties of Spanish, and closed syllables correlate with reduced vowel duration. More raising in closed syllables would support my Weakening Hypothesis.

I expect that vowel raising will be more frequent after a palatal consonant or a tonic high vowel, as previous studies have shown. I expect the same type of influence from the following sound as well. This would be a result of coarticulation, where the high articulation of the adjacent consonant or previous vowel causes the tongue to maintain a higher position for the following sound, thus favoring the raised vowel. Or in the case of the following sound, the tongue aims toward a higher position in the mouth in anticipation of the following sound.

Based on my initial impressions, I expect to find raising in clitics and in the non-final position of the word, although these contexts have not been widely considered in previous literature. I hope to show that these contexts should definitely be considered within the envelope of variation because they are places where variation can occur.

Given that unstressed vowel devoicing is more frequent in utterance final position, I predict that there will be more raising in this same position, since I consider vowel raising as a weakening process. More raising in this position would be evidence to support my Weakening Hypothesis.
• As for the social factors, I expect more raising from the participants in the closed network. Since they have less exposure to other varieties of Spanish, they are more likely to maintain non-standard features in their speech. Alternatively, members of the open network will have more contact with other dialects of Spanish, may be more aware of the stigma associated with the use of non-standard features, and therefore use a more standard pronunciation.
Chapter 4. Results

This chapter discusses the results for each of the two mid vowels from both the categorical (DAPC) and continuous (F1 and F2) analyses. I begin section 4.1 with an explanation of the overall descriptive results and section 4.2 follows up with the presentation of the variable selection and statistical models. Section 4.3 details the results for the independent variables that were chosen as significant by the statistical models for each vowel (/e/ and /o/). In section 4.4, I present a summary of the results for all of the dependent variables.

4.1 Descriptive statistical results

In this section I present the overall patterns that we see in the data in regards to raising and non-raising as well as the changes in formant values. I include a detailed explanation of both the creation of a categorical distinction between raised and non-raised vowels based on formant value measurements using a Discriminant Analysis of Principal Components (DAPC; (Jombart 2008, Jombart, Devillard and Balloux 2010), described below, and its analysis as well as a continuous formant analysis. I discuss how the data is divided between the raised and non-raised categories and then look at the tendencies
based on the formant values themselves. As I mentioned in chapter 3, for both the
categorical and continuous analyses, I look at /o/ and /e/ separately.

4.1.1 Categorical Analysis

In order to create a binary distinction between the raised and non-raised vowel
tokens, I used the Discriminant Analysis of Principal Components (DAPC; Jombart 2008,
Jombart, Devillard and Balloux 2010). I had originally completed an auditory analysis
where I listened to each token individually and determined whether or not it was raised.
Up until recently this had been the most widely used strategy for previous studies on
vowel raising, as discussed in section 2.3.5. However, recent work on vowel raising in
Asturias by Barnes (2013) has demonstrated the benefits of using the DAPC, a method
that has also proved to be successful in perception studies aimed at determining the role
of formant frequencies in distinguishing between male and female voices (Hillenbrand
and Clark 2009). Barnes was the first to apply DAPC to the analysis of vowel raising.
DAPC is a multivariate analysis that can be used to identify clusters or groups within data
by maximizing the differences between the groups. For my own analysis of vowel raising
I chose two categories, raised and non-raised, and used the first and second formant
values as the input to the DAPC algorithm (following Barnes’ method). The DAPC
determines the statistical probability of belonging to one of the two groups for each
vowel token.

Barnes (2013) describes that there are several reasons that the DAPC presents a
more reliable method than an auditory analysis for making the determination between
raised and non-raised vowels. First of all, it eliminates the subjective interpretation of the investigator by using statistical probabilities, thus getting rid of any possible bias. Secondly, the model used to determine the grouping eliminates the arbitrariness of the auditory decision. This is especially useful for the cases that are not clearly identifiable as raised or non-raised. Finally, since the judgment is based on the measurements of both the first and second formants, it presents a more complex description than a judgment based solely on auditory perception.

Figures 6-9 show a cross between the first two formant values and the two types of categorical analysis, auditory and DAPC, for /o/ and /e/. For each figure, F1 is on the y-axis and F2 is on the x-axis, where triangles represent the raised tokens and circles represent the non-raised tokens, based on the auditory analysis in figures 6 and 8 and on the DAPC in figures 7 and 9. In both the auditory judgments and the DAPC for /o/, we see that the F1 value, rather than the F2 value, plays a role in the raised or non-raised distinction. The raised tokens of /o/ tend to have lower F1 values, while non-raised tokens tend to have higher F1 values. For both raised and non-raised tokens there is quite a range of F2 values, although we could say that there is a slight tendency for raised tokens to have higher F2 values and non-raised tokens to have lower F2 values. The similarities between the auditory judgments and the DAPC analysis can also be seen for /e/, in figures 8 and 9, where we see that both F1 and F2 have an impact on the raised or non-raised distinction. The raised tokens of /e/ tend to have lower F1 values and higher F2 values than the non-raised tokens.
The differences between the auditory judgments and the grouping based on the DAPC results can also be seen quite clearly in figures 6-9. There are many cases of category overlap in the auditory judgments, meaning that two tokens that have similar F1 and F2 values have been categorized distinctly based on the auditory analysis, with one being judged as raised and the other as non-raised. On the contrary, the DAPC creates a clear division between the raised and non-raised categories.

Figure 6: Auditory distribution of /o/ in the vowel space
In figure 7 we can also see that for /o/ there are many more non-raised than raised tokens. We can compare this with figure 9 where we see that the opposite is true. For /e/ there are more raised than non-raised tokens. Table 11 presents the raw data numbers and percentage of occurrence in the raised and non-raised categories as determined by the DAPC. As we can see, there are more total tokens of /o/ than /e/ and the front mid vowel, /e/, is much more likely to be raised than the back mid vowel, /o/.
Figure 8: Auditory distribution of /e/ in the vowel space

Figure 9: DAPC distribution of /e/ in the vowel space
<table>
<thead>
<tr>
<th>Vowel</th>
<th>Non-raised</th>
<th>Raised</th>
<th>Total N</th>
</tr>
</thead>
<tbody>
<tr>
<td>/e/</td>
<td>412 (23%)</td>
<td>1383 (77%)</td>
<td>1795</td>
</tr>
<tr>
<td>/o/</td>
<td>2447 (88%)</td>
<td>344 (12%)</td>
<td>2791</td>
</tr>
</tbody>
</table>

Table 11: Distribution of raised and non-raised tokens as determined by the DAPC

In figure 10 we can see the overall distribution of the data by speaker. On the x-axis we see the individual speakers and on the y-axis we see the percentage of raising for both /e/ and /o/. The darker color indicates /e/ raising and the lighter color /o/ raising. For all speakers we see the same trend of more /e/ raising than /o/ raising. Nearly all the speakers are raising the /e/ tokens at least 50% of the time, with the majority raising /e/ over 75% of the time. For /o/ we see the opposite trend, with most speakers raising /o/ less than 25% of the time.
4.1.2 Acoustic Analysis

As I discussed in section 3.3.2, the formant values (F1 and F2) for each vowel token were taken from the midpoint of the vowel. The formant values were then
normalized to account for anatomical differences among the speakers due to differences in vocal tract length due to age and gender. Using these normalized formant values, I then compared the raised and non-raised tokens, as determined by the DAPC, for each formant separately. Because /o/ is a back mid vowel and /e/ is a front mid vowel, we would expect the second formant values to undergo changes in different directions as an effect of raising. That is, we would expect lower F2 values for raised /o/ tokens and higher F2 values for raised /e/ tokens, if there is a change in F2 to accompany the lowering of F1. Therefore, in addition to the differences in behavior of the two vowels found in previous studies and mentioned in section 3.4.1, /o/ and /e/ tokens must be considered separately for their formant differences as well.

4.1.2.1 Acoustic results for /o/

Figure 11 shows that /o/ tokens that were categorized as raised by the DAPC have different formant values than those categorized as non-raised. This is true for both F1 and F2. We can see in the boxplots in figure 11 that the raised /o/ tokens have a lower F1 value, which corresponds to the higher position of the tongue in the mouth. This is what we would expect considering that the raising of the vowel is predominantly captured by the height, as measured by F1. The raised /o/ tokens have a higher F2 value, which indicates that the articulation is more towards the front of the mouth than the non-raised tokens. This is actually the opposite of what we would expect, but we should also note that there is quite a bit of overlap in the F2 values for the raised and non-raised productions when compared to the F1 values.
In order to determine whether the formant values for the raised and non-raised tokens are significantly different, I used a one-tailed test of significance which determines whether the F1 value is significantly greater in the non-raised tokens than in the raised tokens of /o/. The p-value confirms that tokens that have been categorized as non-raised have a statistically higher F1 value and the raised tokens have a lower F1
value (t = 54.7509, df = 583.616, p-value < .001). This same test was run for F2 as well
and indicates that the F2 values are significantly lower in the non-raised tokens of /o/ (t =
-6.5255, df = 413.979, p<.001). The differences in formant values displayed in the
boxplots are not surprising, since they are based on the statistical differences determined
by the DAPC, but it is reassuring to see that the boxplots do indeed corroborate with the
DAPC distinction between raised and non-raised tokens. Considering that we would
expect lower F2 values to be associated with the higher back vowel /u/, rather than /o/,
this is a bit surprising. It should also be noted, however, that we may not expect to see a
correspondence between vowel raising and F2 values, since raising is mainly determined
by the F1 values.

4.1.2.2 Acoustic results for /e/

The boxplots for /e/ are shown in figure 12, where we can clearly see a difference
in both F1 and F2 values based on whether the tokens were categorized as raised or non-
raised by the DAPC. We can see that raised /e/ tokens have lower F1 values, which
corresponds to a higher position of the tongue in the mouth. The F2 values of raised /e/
tokens are higher, which corresponds to an articulation more towards the front of the
mouth. The same one-tailed test of significance was used for /e/ as was used for /o/ and
demonstrates that the non-raised /e/ tokens have significantly greater F1 values than the
raised tokens (t = 25.6242, df = 628.997, p<.001). As for the F2 values, the one-tailed test
shows that the values are significantly lower in the non-raised tokens (t = -18.2159, df =
517.542, p-value < .001).
4.2 Statistical models

In order to test the effect of the linguistic and social independent variables on the dependent variables, I used logistic and linear regression models in R (R Development Core Team 2011). I developed mixed effects models using speaker as a random variable to account for differences based on the individual speaker. This was done using the `glmer` and `lmer` functions in R (Bates et al. 2014). Including speaker as a random variable is ideal since the data set is based on a large number of tokens from a smaller set of
speakers. As Tagliamonte points out, “Statisticians argue that we must have statistical validation that predictors are statistically significant over and above the individuals that happen to be in the sample and the words they use” (20012:137). Thus, the mixed effects model helps to ensure that the effects on the dependent variable are coming from the independent variables and not from the individual speakers. One of the advantages of using mixed effect models is that both fixed and random effects, speaker in this case, can be included. Also, mixed effects models tend to error on the side of caution, where effects may be found to be non-significant when they really are, rather than the other way around. Thus, this approach is more conservative than using a model that relies solely on fixed effects.

For each dependent variable I first used random forests to determine the ranking of the importance of the predictors, using the cforest function from the party package in R (Hothorn et al. 2013) following the methodology of Barnes (2013). The random forests are made up of individual conditional inference trees which compare the independent variables in order to determine which are the most useful predictors of the variant choice. This is done through a process of trial and error, where the sum of the conditional inference trees is what makes up the random forest (Tagliamonte 2012). One of the benefits of using the random forests is that introducing a large number of variables is not a problem, which is especially useful for the current study. Even similar variables or factor groups can be introduced into the same analysis and the variable importance plot clearly shows which are the most relevant. The random forest does not, however, show the significance of the different levels within the independent factor groups or how they
may interact. To examine these interactions, I use a conditional inference tree, which explores the relationships between factor levels. This is done using the `ctree` function from the `party` package in R. The results of the determination of variable importance through the use of random forests, the mixed effects model results, and the conditional inference trees are presented in the following section.

4.3 Results from random forest, mixed effects models, and conditional inference trees

In this section I provide a detailed explanation of the ranking of the independent variables, as determined by the random forest, and the mixed effects logistic or linear model for each of the dependent variables. I then use conditional inference trees to address any interactions among the variables. Before presenting the results for each dependent variable, I also discuss how the numerous levels within each factor for several independent variables were combined into smaller groups. By creating a smaller number of levels within each variable, it decreases the likelihood that a variable will erroneously be picked as significant. When there is a larger number of levels within a variable, the greater amount of variation may inflate the significance of the factor. Thus, merging a large number of categories into smaller groups helps to create a better model for the data. It also helps to eliminate cells with very few tokens, which can also disrupt the effectiveness of some statistical models. Regrouping for several of the independent variables (previous consonant, following sound, lexical category, previous vowel, and tonic vowel) was necessary because there were numerous factor levels. Each of the independent variables that had more than six levels was subject to regrouping. All of the
regrouping was done before the statistical models were run. For each dependent variable discussed below, I will only present the regrouping for the independent variables that were determined to be significant in the statistical analyses. First I present the results for the DAPC for /o/ then /e/, followed by the continuous results of both F1 and F2 for /o/, and finally the continuous results for /e/.

4.3.1 Discriminant Analysis of Principal Components results for /o/

Before examining the significance of the different independent factor groups, let me first discuss how the different levels were grouped together for the previous consonant, lexical category, and tonic vowel variables.

Previous consonant grouping for DAPC for /o/

Originally each of the previous consonants was coded as a separate group, by sound, which also included deleted consonants or contexts with no previous consonant. However, this resulted in approximately 28 levels, which was problematic for the statistical analysis. In order to overcome this problem, first, I regrouped the previous consonants according to their point of articulation, although some groups combine multiple points of articulation, which resulted in seven groups. That is to say, for example, /b/ and /p/ were grouped together because they are both bilabial. Included in these seven groups are cases where there is no previous consonant or when the previous consonant is deleted. The distribution of these seven groups based on their raised or non-raised tokens, determined by the DAPC, is displayed in figure 13. Note that this figure
shows the initial grouping of the previous consonant tokens. The x-axis displays the
percentage of non-raised tokens and the y-axis shows the percentage of raised tokens.
Note that the /o/ tokens are all more likely to be non-raised than raised. For example, the
tokens in group 6 are raised 25% of the time and non-raised 75% of the time. In the
opposite corner, tokens in group 7 are raised 100% of the time and never non-raised.
While most of the groups are spaced apart, indicating that they act differently, groups
three and five show a similar pattern and were therefore combined. This is indicated in
the figure with the circle around groups three and five. The resulting six groups, which
are the final groups used in the statistical analysis for the previous consonant category,
are shown in table 12.
Figure 13: Initial grouping by previous consonant for DAPC for /o/

<table>
<thead>
<tr>
<th>Groups</th>
<th>Previous consonant (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no previous consonant</td>
</tr>
<tr>
<td>2</td>
<td>palatal</td>
</tr>
<tr>
<td>3</td>
<td>bilabial, labio-dental</td>
</tr>
<tr>
<td>4</td>
<td>dental, alveolar</td>
</tr>
<tr>
<td>5</td>
<td>consonant cluster ending in alveolar, velar</td>
</tr>
<tr>
<td>6</td>
<td>deleted</td>
</tr>
</tbody>
</table>

Table 12: Final grouping by previous consonant for DAPC for /o/
Lexical category grouping for DAPC for /o/

In the original determination of lexical category there were eleven different levels which were categorized as the following: adjective, adverb, determiner, clitic, interjection, noun, pronoun, verb, preposition, or conjunction. We see the initial presentation of the raising tendencies of these categories in figure 14. Again, we see that all the /o/ tokens are more likely to be non-raised than raised. The tokens in the categories near the top left corner are raised the most, around 15% of the time, and the tokens in the categories in the bottom right corner are non-raised 100% of the time. In order to have fewer levels within the lexical category variable, I combined categories that acted in a similar manner. The new grouping is indicated by the circles around the categories which were combined. The final five lexical category groups that were used in the statistical analysis are summarized in table 13.
Figure 14: Raising tendencies by lexical category for DAPC for /o/

Table 13: Final grouping by lexical category for DAPC for /o/

<table>
<thead>
<tr>
<th>Groups</th>
<th>Lexical category (LC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pronoun</td>
</tr>
<tr>
<td>2</td>
<td>adjective, noun, verb</td>
</tr>
<tr>
<td>3</td>
<td>preposition, adverb, determiner, clitic</td>
</tr>
<tr>
<td>4</td>
<td>conjunction</td>
</tr>
<tr>
<td>5</td>
<td>possessive pronoun, interjection</td>
</tr>
</tbody>
</table>

Tonic vowel grouping for DAPC for /o/

The tonic vowel category describes the quality of the stressed vowel preceding each vowel token. The raising tendencies of the tonic vowel preceding the /o/ tokens can
be seen in figure 15, where we see that each vowel and diphthong was coded separately. We notice that all the /o/ tokens are more likely to be non-raised than raised. The tokens near the top left corner are raised around 20% of the time while the tokens in the bottom left corner are non-raised close to 100% of the time. Based on similar behavior of the variants I was able to merge the 14 original tonic vowel levels into four groups, which are indicated by the circles around the tonic vowel levels that I combined. Table 14 presents the final grouping of the tonic vowel levels that was used in the statistical analysis.

Figure 15: Raising tendencies by tonic vowel for DAPC for /o/
<table>
<thead>
<tr>
<th>Group</th>
<th><strong>Tonic vowel (TV)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/u, aj, ja/</td>
</tr>
<tr>
<td>2</td>
<td>/wi, i, a, je, e, o/</td>
</tr>
<tr>
<td>3</td>
<td>/wa, we/</td>
</tr>
<tr>
<td>4</td>
<td>/jo, iw, ej/</td>
</tr>
</tbody>
</table>

Table 14: Final grouping by tonic vowel for DAPC for /o/

Now that I have described the regrouping of multiple levels within several independent variables, we can examine the results from the random forest, mixed effects logistic model, and conditional inference tree. The ranking of the importance of the predictors, as determined by the random forest, for the categorical (DAPC) analysis of /o/ is presented in figure 16. For the mixed effects model, speaker was the random variable and the predictors were added one at a time, in a stepwise procedure, in the order of importance suggested by the random forest analysis. Thus, first the word location within the utterance variable was added to the model, followed by previous consonant, type of syllable, lexical category, gender, etc. in order to find the best fit model for the data. Note that tonic vowel and previous vowel were not both added to the model because they normally refer to the same vowel. Since tonic vowel was rated as more important than previous vowel in the random forest, it was included in this model.
Figure 16: Variable importance as determined by the random forest for the DAPC analysis of /o/.\textsuperscript{15}

After I had created thirteen different models, adding the independent variables (except previous vowel) one at a time to each previous model, I ran a series of ANOVAs

\begin{itemize}
  \item Speaker
  \item Location
  \item PCgroup.DAPC
  \item Syllable.type
  \item Lexical.category.DAPC
  \item Gender
  \item FSgroup.DAPC
  \item TVgroup.DAPC
  \item PVgroup.DAPC
  \item X..syllables
  \item Type.of.stress
  \item Social.network
  \item Spaces.from.stressed.syllable
  \item Clitic.not
  \item Final.non_final
\end{itemize}

\textsuperscript{15} I would like to clarify the abbreviations for the independent variables and note that this same legend will also be used in figures 22, 27, 31, 35, and 41. Further explanation of each variable is found in section 3.4.2.1. Location = word location within the utterance. PCgroup.DAPC = previous consonant, Syllable.type = type of syllable, Lexical.category.DAPC = lexical category, FSgroup.DAPC = following sound, TVgroup.DAPC = tonic vowel, PVgroup.DAPC = previous vowel, X..syllables = number of syllables in the word, Type.of.stress = stress pattern, Spaces.from.stressed.syllable = distance (in syllables) away from the tonic syllable, Clitic.not = whether the token is in a clitic or not, Final.non-final = position of the vowel within the word.
to compare the models. I looked at which model was significantly better than the previous one and created a new set of models adding only the factors that improved the models. I then ran a series of ANOVAs with the second set of models to find the best fit for the data set. The best fit model for the DAPC analysis of /o/ included the following factors: word location within the utterance, previous consonant (PC), type of syllable, lexical category (LC), tonic vowel (TV), and social network. I will focus on the independent variables that were determined to be significant for raising in the best fit model for the DAPC of /o/. These results are presented in table 15, with the significant factor levels in bold. Note that a positive estimate indicates more raising and a negative estimate indicates less raising.
First of all, tokens located within an utterance are significantly less likely to be raised than those in utterance final position. The previous consonant group also came out as significant in the statistical analysis. Target vowels with previous consonant clusters would...
ending in an alveolar consonant and velars (PC group 5), and dental and alveolar consonants (PC group 4) have significantly less raising than the target vowels with no previous consonant (PC group 1). An example of no previous consonant is *novi*o ‘boyfriend’. By changing the reference level, I can make comparisons among all the levels. Target vowels with previous consonant clusters ending in an alveolar consonant and velars (PC group 5), and dental and alveolar consonants (PC group 4) have significantly less raising than the target vowels with a previous palatal (PC group 2) or bilabial or labio-dental consonant (PC group 3). Tokens after a dental or alveolar consonant are significantly more likely to be raised than tokens after the consonant clusters and velars. There are no other statistical differences between the levels of previous consonant. Table 16 shows the raising tendencies for the previous consonant groups. The most raising occurs when there is no previous consonant, followed by a previous palatal, then previous bilabials and labio-dentals, then previous dentals and alveolars, and followed by previous consonant clusters ending in alveolars and previous velars. The group with the least raising is the deleted previous consonant.

<table>
<thead>
<tr>
<th>More raising</th>
<th>Less raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>no previous consonant (PC group 1)</td>
<td>deleted (PC group 6)</td>
</tr>
<tr>
<td>palatal (PC group 2)</td>
<td></td>
</tr>
<tr>
<td>bilabial and labio-dental (PC group 3)</td>
<td></td>
</tr>
<tr>
<td>dental and alveolar (PC group 4)</td>
<td></td>
</tr>
<tr>
<td>velar and consonant cluster ending in alveolar (PC group 5)</td>
<td></td>
</tr>
</tbody>
</table>

Table 16: Raising tendencies by previous consonant (PC) for DAPC for /ɔ/
As for the type of syllable, the statistical analysis shows that there is more raising in closed syllables than open syllables. In the lexical category, prepositions, adverbs, determiners, and clitics (LC group 3) and conjunctions (LC group 4) are less likely to be raised than pronouns (LC group 1), which is the level with the most raising. There are no statistical differences between any of the other levels within the lexical category factor, however we can see the raising tendencies in table 17. Pronouns have the most raising, followed by adjectives, nouns, and verbs, then prepositions, adverbs, determiners, and clitics, and then conjunctions. The level with the least raising is the lexical category group of possessive pronouns and interjections.

<table>
<thead>
<tr>
<th>More raising</th>
<th>Less raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>pronoun (LC group 1)</td>
<td>possessive pronoun, interjection (LC group 5)</td>
</tr>
<tr>
<td>adjective, noun, verb (LC group 2)</td>
<td></td>
</tr>
<tr>
<td>preposition, adverb, determiner, clitic (LC group 3)</td>
<td></td>
</tr>
<tr>
<td>conjunction (LC group 4)</td>
<td></td>
</tr>
</tbody>
</table>

Table 17: Raising tendencies by lexical category (LC) for DAPC for /o/

For the tonic vowel factor, tokens with the tonic vowels /wi, i, a, je, e, o/ (TV group 2) and /wa, we/ (TV group 3) are significantly less likely to be raised than when the tonic vowel is /u, aj, ja/ (TV group 1). If I change the reference level, there are no significant differences between the other tonic vowel groups. However, we can look at the general raising tendencies in table 18.
More raising

-/u, aj, ja/ (TV group 1)
-/wi, i, a, je, e, o/ (TV group 2)
-/wa, we/ (TV group 3)
-/jo, iw, ej/ (TV group 4)

Less raising

Table 18: Raising tendencies by tonic vowel (TV) for DAPC for /o/

We see less raising in the open social network than in the closed social network. We can see a display of the percentage of raising by the social networks in figure 17, where the dark portion indicates non-raised /o/ tokens and the light gray indicates the raised /o/ tokens. The closed social network has more members, 26, than the open social network, only five members, indicated by the width of the bars in the bar graph, and there is significantly more /o/ raising in the closed network group.
Now that I have presented the results from the logistic mixed effects model, I present the conditional inference tree based on the DAPC for /o/. Using the variable importance plot generated by the random forest (see figure 16) I created a conditional inference tree, using the party package in R, to look at any interactions between the independent variables. I included the factors that were determined to be statistically

Figure 17: Differences in raising of /o/ based on social network for DAPC
significant by the mixed effects model. For this conditional inference tree, presented in figure 18, I included the following independent variables: word location within the utterance, previous consonant (PC), type of syllable, lexical category (LC), tonic vowel (TV), and social network.

Figure 18: Conditional inference tree based on the DAPC for /o/

The first thing that we notice is that there are low levels of /o/ raising overall, which is illustrated by the bar graphs at the bottom of the conditional inference tree in figure 18. The conditional inference tree first indicates that the location of the word within the utterance is influential in the raising distinction. There is more raising of the target vowels in utterance final position, but we can also see an interaction with the social
network. Members of the closed network are more likely to raise /o/ in words in utterance final position, than members of the open network, and this difference is significant. When we consider the position within the utterance, we see that tokens in a closed syllable are raised more often, regardless of the other independent factors, which is what we would expect. Tokens in an open syllable, however, are constrained by the tonic vowel and the previous consonant. Target vowels in an open syllable with a tonic vowel that belongs to the first tonic vowel group, /u, aj, ja/, are more likely to be raised than tokens with any other tonic vowel (see table 14 for tonic vowel groups). For tokens that belong to the other tonic vowel groups, those that have either no previous consonant or a previous palatal consonant are more likely to be raised than other previous consonant groups. The importance of the results from the logistic mixed effects model their implications will be discussed in the next chapter after the results have been presented for all of the dependent variables. Next, I will present the results for the DAPC for /e/.

4.3.2 Discriminant Analysis of Principal Components results for /e/

Before moving forward with the examination of the significance of the different independent factor groups, let me first discuss how the levels within the following sound, lexical category, and previous consonant variables were grouped together.

Following sound grouping for DAPC for /e/

In the original coding of the following sound category each sound was coded for individually. In order to reduce the number of levels within the variable as I did for /o/, I
first grouped the sounds based on point of articulation, except in the case of no following sound, which was its own group. This resulted in seven groups. I then examined the pattern of raising for this grouping as seen in figure 19. Note that for /e/ there are more raised than non-raised tokens. The groups near the top left corner of the figure have over 80% raising and the group near the bottom right corner has approximately 35% of non-raised tokens and 65% raising. There were several sets of groups that had similar behavior and therefore I reduced the initial grouping by point of articulation to three final levels for the following sound variable. The final groups are noted by the circles in figure 19, which indicate the combination of several levels within the factor. The final grouping of the following sound variable used in the statistical analysis for /e/ is summarized in table 19.
Figure 19: Initial grouping by following sound for DAPC for /e/

<table>
<thead>
<tr>
<th>Groups</th>
<th>Following sound (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>palatal, velar, bilabial, no following sound</td>
</tr>
<tr>
<td>2</td>
<td>dental, alveolar</td>
</tr>
<tr>
<td>3</td>
<td>labio-dental</td>
</tr>
</tbody>
</table>

Table 19: Final grouping by following sound for DAPC for /e/

Lexical category grouping for DAPC for /e/

Initially each token for the lexical category factor was categorized as one of the following: adjective, adverb, determiner, clitic, interjection, noun, pronoun, verb,
preposition, or conjunction. In order to condense the number of levels within this factor, I looked at the patterns of percentage of raising of the tokens shown in figure 20. Note that the levels that fall to the left of the line are more likely to be raised than non-raised and those to the right of the line are more likely not to be raised. Based on the distribution of the data, three lexical category groups were chosen, and this is indicated by the circles around the new grouping in figure 20. The final three lexical category groups that were used in the statistical analysis are summarized in table 20.

Figure 20: Raising tendencies by lexical category for DAPC for /e/
Groups | Lexical category (LC)
---|---
1 | adjective, clitic, determiner, interjection, noun, pronoun, verb, adverb
2 | conjunction
3 | preposition

Table 20: Final grouping by lexical category for DAPC for /e/

Previous consonant grouping for DAPC for /e/

Originally I coded each of the previous consonants separately, based on the different sounds they produce, or whether there was no previous consonant or a deleted previous consonant. However, this resulted in 25 groups, which could cause a problem for the statistical analysis because the chance of any one level acting significantly different than another level is quite high, which may make this factor appear more significant in the raising decision than it really is. The first step in the grouping procedure was to group the consonants together by their point of articulation, or whether there was no previous consonant or it was deleted. After organizing the consonants based on their articulation, I then had seven groups, rather than 25, which we can see in figure 21. Note that several groups combine tokens from different point of articulation categories to adjust for cells with only a few tokens. The next step in the grouping of the previous consonants was to see how the tokens were distributed into the raised and non-raised categories based on the groups that are organized by point of articulation. Note, again, in figure 21 that factors above the line are more likely to be raised and factors below the line are less likely to be raised. As we can see, groups two and three act quite similarly. Thus, these levels were combined. The circles in the figure denote the final combination of
levels within the factor. The final grouping of the previous consonant factor levels resulted in six separate groups as shown in table 21, and this was the grouping used in the statistical analysis.

Figure 21: Initial grouping by previous consonant for DAPC for /e/
Now that we have explored how the levels within these three variables were grouped together, we can return to the discussion of the independent factors that were determined to contribute significantly to raising in the best fit model for the DAPC analysis of /e/. The ranking of the importance of predictors, as determined by the random forest, is presented in figure 22. Using the same methods that were used for the DAPC analysis of /o/, a logistic mixed effects model was created, with speaker as the random variable, and the predictors were added one at a time, in a stepwise procedure. Thus, first the following sound factor was added to the model, followed by previous vowel, lexical category, previous consonant, etc. in order to find the best fit model for the data. Note that in this random forest previous vowel is ranked higher than tonic vowel, and that is why the former is included in the statistical model and not the latter.
Figure 22: Variable importance as determined by the random forest for the DAPC analysis of /e/.

After adding each variable to the model one by one, I then compared the thirteen different models using a series of ANOVAs to determine which independent variables significantly improved the model. I then created a second set of models using only the variables that improved the previous models and performed a second series of ANOVAs to compare the models. The best fit model for the DAPC analysis of /e/ included the following factors: following sound (FS), lexical category (LC), previous consonant (PC), and stress pattern. In table 22 the factor levels that are significant are shown in bold type.
Note that positive estimate values indicate more raising and negative estimate values indicate less raising.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>z-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>1.50</td>
<td>0.66</td>
<td>2.28</td>
<td>0.02</td>
</tr>
<tr>
<td>Following sound (reference is ‘FS group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS group 2</td>
<td>-0.61</td>
<td>0.13</td>
<td>-4.77</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FS group 3</td>
<td>-0.30</td>
<td>0.89</td>
<td>-0.34</td>
<td>0.74</td>
</tr>
<tr>
<td>Lexical category (reference is ‘LC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC group 2</td>
<td>-1.93</td>
<td>1.21</td>
<td>-1.60</td>
<td>0.11</td>
</tr>
<tr>
<td>LC group 3</td>
<td>-1.91</td>
<td>0.39</td>
<td>-4.90</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous consonant (reference is ‘PC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC group 2</td>
<td>-0.62</td>
<td>0.58</td>
<td>-1.06</td>
<td>0.29</td>
</tr>
<tr>
<td>PC group 3</td>
<td>-1.04</td>
<td>0.61</td>
<td>-1.70</td>
<td>0.09</td>
</tr>
<tr>
<td>PC group 4</td>
<td>-1.71</td>
<td>0.62</td>
<td>-2.77</td>
<td>0.01</td>
</tr>
<tr>
<td>PC group 5</td>
<td>-1.59</td>
<td>1.39</td>
<td>-1.15</td>
<td>0.25</td>
</tr>
<tr>
<td>PC group 6</td>
<td>-14.80</td>
<td>73.90</td>
<td>0.20</td>
<td>0.84</td>
</tr>
<tr>
<td>Stress pattern (reference is ‘antepenultimate’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penultimate</td>
<td>1.06</td>
<td>0.27</td>
<td>3.90</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 22: Factors that contribute to /e/ raising in the DAPC analysis

Within the following sound group, we see that target vowels before a dental or alveolar (FS group 2) are less likely to be raised than before a bilabial, palatal, velar, or no following sound (FS group 1). There are no significant differences between following sound groups two and three, but the raising tendencies for the following sound can be seen in table 23. We see that tokens followed by bilabials, palatals, velars, or no
following sound are raised the most, followed by the dentals and alveolars, and finally the labio-dentals, which are raised the least.

<table>
<thead>
<tr>
<th>More raising</th>
<th>Less raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>bilabial, palatal, velar, no following sound (FS group 1)</td>
<td></td>
</tr>
<tr>
<td>dental, alveolar (FS group 2)</td>
<td></td>
</tr>
<tr>
<td>labio-dental (FS group 3)</td>
<td></td>
</tr>
</tbody>
</table>

Table 23: Raising tendencies by following sound (FS) for DAPC for /e/

For the lexical category variable, target vowels that are in prepositions (LC group 3) are less likely to be raised than those in the group containing adjectives, clitics, determiners, interjections, nouns, pronouns, verbs, and adverbs (LC group 1). There were no significant differences between lexical category levels two and three. However, we can see the raising tendencies in table 24, where the conjunctions are raised less than the first lexical category level, but more than the prepositions.

<table>
<thead>
<tr>
<th>More raising</th>
<th>Less raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>adjective, clitic, determiner, interjection, noun, pronoun, verb, adverb (LC group 1)</td>
<td></td>
</tr>
<tr>
<td>conjunction (LC group 2)</td>
<td></td>
</tr>
<tr>
<td>preposition (LC group 3)</td>
<td></td>
</tr>
</tbody>
</table>

Table 24: Raising tendencies by lexical category (LC) for DAPC for /e/

With the previous consonant variable, we see a significant difference between the palatals (PC group 1) and the consonant clusters ending in an alveolar consonant (PC
group 4). Tokens in the latter group are less likely to be raised than in the former group. Changing the reference level to compare the levels within the previous consonant variable shows that target vowels with previous alveolars, dentals, and velars (PC group 2) and bilabials and labio-dentals (PC group 3) are also more likely to be raised than target vowels with previous consonant clusters ending in an alveolar consonant (PC group 4). No other significant differences were found between the previous consonant levels. We do find the following tendencies shown in Table 25. For the stress pattern variable, target vowels in words with stress in the penultimate syllable were more likely to be raised than in words with stress in the antepenultimate syllable.

<table>
<thead>
<tr>
<th>More raising</th>
<th>Less raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>palatal (PC group 1)</td>
<td>consonant cluster with alveolar (PC group 4)</td>
</tr>
<tr>
<td>alveolar, dental, velar (PC group 2)</td>
<td>deleted previous consonant (PC group 6)</td>
</tr>
<tr>
<td>bilabial and labio-dental (PC group 3)</td>
<td>no previous consonant (PC group 5)</td>
</tr>
</tbody>
</table>

Table 25: Raising tendencies by previous consonant (PC) for DAPC for /e/

After having examined the results from the logistic mixed effects model, we will now explore the interactions among the independent variables using the conditional inference tree for the DAPC for /e/. I created the conditional inference tree just as I did for /o/, including only the significant factors in the same way as well. For this conditional inference tree, presented in Figure 23, I included the following independent variables: following sound (FS), lexical category (LC), previous consonant (PC), and stress pattern.
The first thing that we notice is that overall there is much more raising than we saw with /o/. This is evident in the bar charts at the bottom of figure 23. The first division in the conditional inference tree is based on lexical category where groups two and three have significantly less raising than group one (see table 20 for a list of the included categories in each group), which interacts with following sound (see table 19). For following sound groups two and three, tokens that have a previous consonant that is palatal, alveolar, dental, or velar are more likely to be raised than the other previous consonant groups (see table 21), which is to be expected. For following sound group one,
we see that the stress pattern plays a role, and tokens in a word with penultimate stress are more likely to be raised than tokens in antepenultimate stress. A discussion of the results for the DAPC for /e/ is presented in the following chapter. I now move away from the DAPC analysis to elaborate on the results for the continuous formant analyses, first for /o/ and then for /e/.

4.3.3 Continuous analyses of formant values for /o/

In addition to the categorical DAPC analysis, the normalized formant values were also used to create two continuous variables. For /o/, a lower F1 value is the best indication of raising, since F1 corresponds with tongue height. In the F2 dimension, we may expect lower F2 values as the mid vowel gets closer to the high vowel. Note, however, that there is less space in the vocal tract for the back vowels to move, so we may not see a significant difference in F2 values. I will begin first with the F1 results for /o/ followed by the F2 results.

4.3.3.1 Continuous analysis of F1 values for /o/

Before I begin with the examination of the significance of the different independent factor groups, I will first describe how the levels within the previous consonant, lexical category, and following sound variables were grouped together.
Previous consonant grouping for F1 analysis of /o/

I used the same initial grouping method for the previous consonant variable that I used for the DAPC. I first took the individual sounds that I had coded separately and grouped them by point of articulation. This initial grouping is the same as was used for the DAPC analyses and is presented in table 26. Note that group two includes both alveolar and dental consonants.

<table>
<thead>
<tr>
<th>Group</th>
<th>Previous consonant (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>palatal</td>
</tr>
<tr>
<td>2</td>
<td>alveolar, dental</td>
</tr>
<tr>
<td>3</td>
<td>velar</td>
</tr>
<tr>
<td>4</td>
<td>bilabial, labio-dental</td>
</tr>
<tr>
<td>5</td>
<td>consonant cluster with alveolar</td>
</tr>
<tr>
<td>6</td>
<td>no previous consonant</td>
</tr>
<tr>
<td>7</td>
<td>deleted previous consonant</td>
</tr>
</tbody>
</table>

Table 26: Initial grouping of previous consonant by point of articulation

The second step in the reduction of the levels in the previous consonant group is different than what was done for the DAPC. Remember that the DAPC is a categorical raised and non-raised distinction and I looked at the percentage of raising to determine the groups. The F1 values of /o/ are a continuous variable, so I determined the mean formant frequency for each of the seven point of articulation categories. I then plotted the mean formant frequencies to decide on the grouping of levels that acted similarly. In figure 24 we see the normalized F1 frequencies on the y-axis and the initial previous consonant groups (see table 26) on the x-axis. The horizontal red lines indicate an equal division among the range of F1 frequencies and this was used to help determine the
differences between the groups. I then reduced the seven groups to four based on the average formant values and their distribution. The circles in the figure represent the groups that were combined and table 27 provides a summary of the final grouping of previous consonant levels that was used in the statistical model for the F1 analysis of /o/.

Figure 24: Mean F1 values for /o/ by initial previous consonant group
Lexical category grouping for F1 analysis of /o/

The lexical category variable for F1 of /o/ initially had twelve levels, which are the same ones we saw in the DAPC analyses. In order to reduce the number of levels, I first looked at the distribution of the average formant frequency for each lexical category in the same way that I did for the previous consonant variable above. In figure 25 we see the differences in mean formant values among the categories. Based on similar patterns in formant frequencies, I combined several of the lexical categories and reduced the number of levels to three. This is shown by the circles around the lexical categories in figure 25. Table 28 displays the final three lexical category groups that were used in the statistical analysis for F1 of /o/.

<table>
<thead>
<tr>
<th>Group</th>
<th>Previous consonant (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no previous consonant, palatal, bilabial, labio-dental, consonant cluster with alveolar</td>
</tr>
<tr>
<td>2</td>
<td>velar</td>
</tr>
<tr>
<td>3</td>
<td>alveolar, dental</td>
</tr>
<tr>
<td>4</td>
<td>deleted previous consonant</td>
</tr>
</tbody>
</table>

Table 27: Final previous consonant groups for F1 analysis of /o/
Figure 25: Mean F1 values for /o/ by lexical category

<table>
<thead>
<tr>
<th>Group</th>
<th>Lexical category (LC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>possessive pronoun, interjection, determiner, pronoun</td>
</tr>
<tr>
<td>2</td>
<td>adjective, noun, verb, adverb, clitic, preposition</td>
</tr>
<tr>
<td>3</td>
<td>conjunction</td>
</tr>
</tbody>
</table>

Table 28: Final lexical category groups for F1 analysis of /o/
Following sound grouping for F1 analysis of /o/

I originally coded for each following sound individually, so for the first step in the grouping of the following sound category I grouped each sound by the point of articulation. This initial grouping is the same grouping that was used for the DAPC analyses. The resulting seven groups for the initial grouping of the following sound factor are presented in table 29.

<table>
<thead>
<tr>
<th>Group</th>
<th>Following sound (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>palatal</td>
</tr>
<tr>
<td>2</td>
<td>velar</td>
</tr>
<tr>
<td>3</td>
<td>no following sound</td>
</tr>
<tr>
<td>4</td>
<td>bilabial</td>
</tr>
<tr>
<td>5</td>
<td>alveolar</td>
</tr>
<tr>
<td>6</td>
<td>dental</td>
</tr>
<tr>
<td>7</td>
<td>labio-dental</td>
</tr>
</tbody>
</table>

Table 29: Initial grouping of following sound by point of articulation

The next step was to compare the average formant frequency of each of the seven groups in order to reduce the number of levels in the following sound factor. In figure 26 we can see the distribution of the F1 values and the groups that are combined are indicated with circles. The final three following sound groups that were used in the statistical model for F1 of /o/ are presented in table 30.
Figure 26: Mean F1 values for /o/ by initial following sound group

<table>
<thead>
<tr>
<th>Group</th>
<th>Following sound (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no following sound, labio-dental</td>
</tr>
<tr>
<td></td>
<td>alveolar</td>
</tr>
<tr>
<td>2</td>
<td>bilabial, velar, dental, palatal</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Table 30: Final following sound groups for F1 analysis of /o/

We have finished the description of the grouping of levels within several independent variables. Now we will return to the creation of and results for the linear mixed effects model for the F1 analysis of /o/. The first step in creating a linear mixed
effects model for the F1 dependent variable was to determine the ranking of importance of the independent variables through the random forest. We can see this ranking in figure 27, where the most important variables are listed first. Note that the order of the variables differs from the DAPC for /o/ presented in figure 16. Here we see that gender is the most important predictor after the individual speaker. The factors were added to the mixed effects linear model, using speaker as a random variable, in the order displayed in figure 27.
Each of the independent variables was added individually and the models were compared using a series of ANOVAs, in the same way that was done for the logistic models for DAPC. The best fit model for the analysis of F1 for /o/ consisted of the following variables: type of syllable, word location within the utterance, gender, lexical category (LC), previous consonant (PC), and following sound (FS). I present the results from the statistical model in table 31, where the significant factor levels are shown in
bold type. Note that a positive estimate value correlates with a higher F1 value and a negative estimate value indicates a lower F1 value.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>8.58</td>
<td>0.16</td>
<td>53.92</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Type of syllable (reference level is ‘closed’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open</td>
<td>0.25</td>
<td>0.07</td>
<td>3.86</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Word location within the utterance (reference level is ‘utterance final’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within the utterance</td>
<td>0.19</td>
<td>0.06</td>
<td>3.36</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender (reference level is ‘female’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-0.53</td>
<td>0.19</td>
<td>-2.87</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Lexical category (reference level is ‘LC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC group 2</td>
<td>0.16</td>
<td>0.06</td>
<td>2.69</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>LC group 3</td>
<td>0.58</td>
<td>0.10</td>
<td>6.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous consonant group (reference level is ‘PC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC group 2</td>
<td>0.20</td>
<td>0.06</td>
<td>3.29</td>
<td>0.01</td>
</tr>
<tr>
<td>PC group 3</td>
<td>0.28</td>
<td>0.04</td>
<td>6.38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PC group 4</td>
<td>1.42</td>
<td>0.29</td>
<td>4.95</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Following sound group (reference level is ‘FS group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS group 2</td>
<td>0.19</td>
<td>0.07</td>
<td>2.58</td>
<td>0.01</td>
</tr>
<tr>
<td>FS group 3</td>
<td>0.11</td>
<td>0.06</td>
<td>1.84</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 31: Factors that influence F1 frequency for /o/

The results show that the F1 value is significantly higher in open syllables than in closed syllables. Since lower F1 values are an indication of raising, these results coincide with those for the DAPC that show significantly more raising in closed syllables. There
are significantly higher F1 values in target vowels that are in a word within an utterance rather than in utterance final position. Again, this coincides with the DAPC results that show more raising in utterance final position. Gender is also significant, with males showing significantly lower F1 values, i.e. a higher articulation, than females. Although the formant values were normalized to account for gender and age differences, the difference in F1 values between males and females might be based on the length of the vocal tract, especially since gender was not a significant factor in the DAPC. I further discuss these results for gender in chapter 5.

For the lexical category, we see that adjectives, nouns, verbs, adverbs, clitics, and prepositions (LC group 2) and conjunctions (LC group 3) have significantly higher F1 values than possessive pronouns, interjections, determiners, and pronouns (LC group 1). Note that we see a similar pattern to the DAPC where we also see that pronouns correlate with higher levels of raising. By changing the reference level we also find that the conjunctions (LC group 3) have significantly higher F1 values than the adjectives, nouns, verbs, adverbs, clitics, and prepositions (LC group 2). I represent the F1 frequency tendencies for the lexical category variable in table 32. In summary, for this factor the results show that all three levels are statistically different from each other.
For the previous consonant factor, we find that target vowels in previous consonant groups two, three, and four (see table 27) have significantly higher F1 values than target vowels in previous consonant group one. When I change the reference level to compare the levels within the previous consonant variable, the results show that target vowels with a deleted previous consonant (PC group 4) have significantly higher F1 values than the velars (PC group 2) and the dentals and alveolars (PC group 3). There are no other significant differences between the levels for this factor. I show the F1 frequency tendencies for the previous consonant variable in table 33. Notice that we see higher F1 values, i.e. less raising, when the previous consonant is deleted, and lower F1 values, i.e. more raising, when there is a previous palatal or no previous consonant, which coincides with what we saw in the DAPC results.
Higher F1 (less raising)
- deleted previous consonant (PC group 4)
- alveolar, dental (PC group 3)
- velar (PC group 2)
- no previous consonant, palatal, bilabial, labio-dental, consonant cluster with alveolar (PC group 1)

Lower F1 (more raising)

Table 33: F1 frequency tendencies by previous consonant (PC) for /o/

The following sound factor is also significant. The results show that target vowels followed by alveolars (FS group 2) have significantly higher F1 values than target vowels followed by labio-dentals or no following sound (FS group 1). When I change the reference level I find that there are no other significant differences between the levels of the following sound variable. Since this factor was not significant in the DAPC, we can not make any comparisons. I present the F1 frequency tendencies for following sound in table 34.

Higher F1 (less raising)
- alveolar (FS group 2)
- bilabial, velar, dental, palatal (FS group 3)
- no following sound, labio-dental (FS group 1)

Lower F1 (more raising)

Table 34: F1 frequency tendencies by following sound (FS) for /o/

Now that I have presented the results from the linear mixed effects model for /o/, I present the conditional inference tree using F1 frequency as the dependent variable. I created a conditional inference tree, using the party package in R, to look at any interactions between the independent variables. I included the factors that were
determined to be statistically significant by the mixed effects model. For this conditional inference tree, presented in figure 28, I included the following independent variables: type of syllable, word location within the utterance, gender, lexical category (LC), previous consonant (PC), and following sound (FS).

Figure 28: Conditional inference tree based on the F1 values for /o/

Since this conditional inference tree is based on a continuous variable, we see that the measurement beneath the nodes gives us a range of F1 values, which is different than what we saw with the DAPC. The first division is with gender, where we see a significant difference between males and females and their interactions with other independent variables. The gender differences will be discussed further in chapter 5. We will start with the females and we see an interaction with lexical category. Tokens in lexical category groups one and two (see table 28) have lower F1 values than tokens in lexical category group three. Tokens in lexical category groups one and two interact with word
location within the utterance and overall we see lower F1 values utterance-finally, i.e. more raising. When the token is in a word within the utterance, those that are in previous consonant (PC) groups two, three, and four (see table 27) have higher F1 values than those in previous consonant group one. We see an interaction between previous consonant group one and type of syllable, with lower F1 values in closed syllables than in open syllables. We can now move back up to the top of the conditional inference tree to see the interactions for males. The first division is with the previous consonant group, and we see that the previous consonant groups one and two have different interactions than the rest of the previous consonant groups (see table 27). Tokens that belong to the previous consonant group one or two have lower F1 values in words in utterance final position than when they are within an utterance. Now, if we go back to the previous consonant node, we see an interaction between previous consonant groups three and four, and lexical category. Target vowels in these previous consonant groups that are in lexical category two or three (see table 28) generally have higher F1 values than target vowels in lexical category one. For target vowels that belong to lexical category two or three, we see that there is a distinction between previous consonant groups three and four, with higher F1 values in the latter group. Lexical category plays a role for previous consonant group three, and we see lower F1 values when they belong to lexical category group two than lexical category group three. A discussion of the results for the first formant analysis for /o/ is presented in the chapter 5. I will now present the results for analysis of F2 for /o/.
4.3.3.2 Continuous analysis of F2 values for /o/

Before discussing the results for the F2 frequency and its effects on /o/ raising, I first need to describe the grouping of the levels within the following sound and previous consonant independent variables.

Following sound grouping for F2 analysis of /o/

For the following sound factor, I originally coded for each individual sound as I have mentioned in previous analyses. In order to avoid problems with my statistics due to too many factor levels, I then grouped the following sound in the same way that was done for the F1 analysis. I combined the original following sound groups based on point of articulation. These groups can be reviewed in table 29 in section 4.3.3.1. I then calculated the mean F2 value for each of the seven groups and plotted the results to compare the levels. We see the comparison of the following sound groups by point of articulation and arranged by their mean F2 frequency in figure 29. The x-axis indicates the initial following sound group (see table 29) and the y-axis shows the normalized F2 values in order from lowest to highest. The seven initial groups were then reduced to three based on the mean F2 values and this is indicated in figure 29 with the circles around the combined groups. The final levels for the following sound variable that were used for the statistical analysis of F2 for /o/ are presented in table 35.
**Figure 29:** Mean F2 values for /o/ by initial following sound group

<table>
<thead>
<tr>
<th>Group</th>
<th>Following sound (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no following sound, bilabial, velar, labio-dental</td>
</tr>
<tr>
<td>2</td>
<td>alveolar, dental</td>
</tr>
<tr>
<td>3</td>
<td>palatal</td>
</tr>
</tbody>
</table>

Table 35: Final following sound groups for F2 analysis of /o/
Previous consonant grouping for F2 analysis of /o/

The same initial grouping method was used for the previous consonant variable that I presented for F1. The individual sounds that had been coded separately were grouped by point of articulation, which can be seen in table 26 in section 4.3.3.1. These seven groups were then organized by their mean F2 frequency in order to determine further grouping of the levels within the previous consonant factor. This is shown in figure 30, where we see the increasing normalized F2 values on the y-axis and the initial previous consonant groups by point of articulation on the x-axis. The circles indicate the groups that have been combined. The final three previous consonant levels used in the statistical model for F2 of /o/ are presented in table 36.
Figure 30: Mean F2 values for /o/ by initial previous consonant group

<table>
<thead>
<tr>
<th>Group</th>
<th>Previous consonant (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bilabial, labio-dental, velar</td>
</tr>
<tr>
<td>2</td>
<td>alveolar, dental, consonant cluster with alveolar, deleted previous consonant</td>
</tr>
<tr>
<td>3</td>
<td>palatal, no previous consonant</td>
</tr>
</tbody>
</table>

Table 36: Final previous consonant groups for F2 analysis of /o/

Now that we have established the grouping of the levels within the following sound and previous consonant factors, we can move on to the results of the F2 statistical
analysis. The ranking of the importance of the variables was done using the random forest, in the same way that it was done for the F1 analysis. The order of importance for F2 is different than both F1 and the DAPC, and can be seen in figure 31. Interestingly, it is the previous consonant variable that is the most important predictor of F2 frequency, and this is above the effect of the individual speaker. The variables were added to the linear mixed effects model in the order suggested by figure 31, as was done in the previous analyses.

![Figure 31: Variable importance as determined by the random forest for F2 of /o/](image-url)
I created numerous models by adding the independent variables individually and then compared them using a series of ANOVAs. The factors that significantly improved those models were then used to create new models, adding the factors in one at a time. After a series of ANOVA comparisons of the second set of models, I was able to determine the best fit model for the data. The best fit model for the analysis of F2 for /o/ consisted of the following variables: type of syllable, following sound (FS), gender, and previous consonant (PC). I present the results from the statistical model in table 37, with the significant factor levels in bold type. Note that a positive estimate indicates a higher F2 value and a negative estimate indicates a lower F2 value.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>15.65</td>
<td>0.18</td>
<td>85.04</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Type of syllable (reference level is ‘closed’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open</td>
<td>-0.30</td>
<td>0.08</td>
<td>-3.85</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Following sound (reference level is ‘FS group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS group 2</td>
<td>0.69</td>
<td>0.07</td>
<td>9.79</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FS group 3</td>
<td>1.44</td>
<td>0.10</td>
<td>8.63</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender (reference level is ‘female’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-0.72</td>
<td>0.23</td>
<td>-3.15</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Previous consonant group (reference level is ‘PC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC group 2</td>
<td>1.27</td>
<td>0.06</td>
<td>20.18</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PC group 3</td>
<td>2.41</td>
<td>0.10</td>
<td>24.33</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 37: Factors that influence F2 frequency for /o/
The type of syllable is significant for the determination of F2 frequency. Target vowels in open syllables have significantly lower F2 values than in closed syllables. For the following sound variable, target vowels followed by alveolars and dentals (FS group 2) and palatals (FS group 3) have significantly higher F2 frequencies than target vowels followed by bilabials, velars, labio-dentals or no following sounds (FS group 1). When I change the reference level, the results show that target vowels with following palatals (FS group 3) have significantly higher F2 values than target vowels followed by alveolars and dentals (FS group 2). Thus, the three following sound levels are all statistically different from each other. I show the F2 frequency tendencies in table 38.

<table>
<thead>
<tr>
<th>Higher F2 (more fronted)</th>
<th>Lower F2 (less fronted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>palatal (FS group 3)</td>
<td>bilabial, velar, labio-dental, no following sound (FS group 1)</td>
</tr>
<tr>
<td>alveolar, dental (FS group 2)</td>
<td></td>
</tr>
</tbody>
</table>

Table 38: F2 frequency tendencies by following sound (FS) for /o/.

Males have significantly lower F2 frequencies than females, which is also what we saw for the F1 frequencies for /o/. For the previous consonant group, target vowels in previous consonant groups two and three have significantly higher F2 values than target vowels in previous consonant group one (see table 36 for previous consonant groups). If I change the reference level, the results show that previous consonant group three has a significantly higher F2 frequency than previous consonant group two. I show the F2
frequency tendencies in table 39, where all the previous consonant factor levels are significantly different from one another.

<table>
<thead>
<tr>
<th>Higher F2 (more fronted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>no previous consonant, palatal (PC group 3)</td>
</tr>
<tr>
<td>alveolar, dental, consonant cluster with alveolar, deleted previous consonant (PC group 2)</td>
</tr>
<tr>
<td>bilabial, velar (PC group 1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower F2 (less fronted)</th>
</tr>
</thead>
</table>

Table 39: F2 frequency tendencies by previous consonant (PC) for /o/

Now that I have finished the results from the linear mixed effects model, I will present the interactions among the independent variables using the conditional inference tree for the analysis of F2 for /o/. As I have done previously, I created the conditional inference tree using all the significant factors from the linear mixed effects model. The conditional inference tree presented in figure 32 includes the following independent variables: type of syllable, following sound (FS), gender, and previous consonant (PC).
The previous consonant is where the first division occurs in figure 32 and we see a distinction between previous consonant (PC) group one (see table 36) and previous consonant groups two and three. Tokens in previous consonant group one show an interaction with the type of syllable, and we see overall higher F2 values in closed syllables than in open syllables. When the tokens are in an open syllable, there is an interaction with gender, and we notice that females have higher F2 values than males. For the males, there is a distinction between following sound (FS) group two and following sound groups one and three (see table 35), where we see higher F2 values in the latter groups. If we go back up to the first node in the conditional inference tree, we see that within the previous consonant group, groups two and three are influenced by different factors. For previous consonant group two, gender plays a role and males have the same interaction with the following sound as they did with the previous consonant group one. That is, tokens from males have higher F2 values when they are in following sound.
groups one and three when compared to following sound group two. Females show precisely the same tendency, that is lower F2 values when the tokens are in following sound group two. If we return to previous consonant group three, we see that tokens in closed syllables have higher F2 values than tokens in open syllables. For tokens in open syllables we see an interaction with gender, and females have higher F2 values than males. The correlation between gender and differences in formant values will be discussed in chapter 5. Overall, we see a tendency that higher F2 values for /o/ correlate with the same contexts where we find raising for the DAPC, i.e. closed syllables, and this will also be discussed further in the following chapter. A discussion of the results for the second formant analysis for /o/ is presented in the chapter 5. I will now present the continuous formant analysis for /e/.

4.3.4 Continuous analyses of formant values for /e/

In the same way that I did with /o/, I used the normalized formant values to create two continuous variables for F1 and F2. Just like we saw for /o/, a lower F1 frequency for /e/ indicates raising. Remember that F1 corresponds with tongue height. In the F2 dimension, we would expect higher F2 values as the mid vowel approaches the high vowel [i]. I will start by first examining the F1 results for /e/ followed by the F2 results.
4.3.4.1 Continuous analysis of F1 values for /e/

Before beginning to discuss the results for the F1 frequency and its effects on /e/ raising, I first need to describe the grouping of the levels within the independent variables of following sound and lexical category.

Following sound grouping for F1 analysis of /e/

For the following sound factor, I originally coded for each individual sound. In order to decrease the number of factor levels, I then grouped the following sound in the same way that was done for the F1 analysis. I combined the original following sound groups based on point of articulation. These groups can be reviewed in table 29 in section 4.3.3.1. I then calculated the mean F1 value for each of the seven groups and plotted the results to compare the levels. We see the comparison of the following sound groups by point of articulation and arranged by their mean F1 frequency in figure 33. The x-axis indicates the initial following sound group and the y-axis shows the normalized F1 values in order from lowest to highest. The seven initial groups were then reduced to three based on the mean F1 values. We see this grouping in figure 33 with the circles around the combined groups. The final levels for the following sound variable that were used for the statistical analysis of F1 for /e/ are presented in table 40.
Figure 33: Mean F1 values for /e/ by initial following sound group

<table>
<thead>
<tr>
<th>Group</th>
<th>Following sound (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>palatal, no following sound</td>
</tr>
<tr>
<td>2</td>
<td>velar, bilabial, alveolar</td>
</tr>
<tr>
<td>3</td>
<td>dental, labio-dental</td>
</tr>
</tbody>
</table>

Table 40: Final following sound groups for F1 analysis of /e/
Lexical category grouping for F1 analysis of /e/

The lexical category variable for F1 of /e/ initially had the same twelve levels as previous analyses. In order to reduce the number of levels, I first looked at the distribution of the average formant frequency for each category as I have done previously. In figure 34 we see the differences in mean formant values among the lexical categories. Based on similar patterns in formant frequencies, I combined several of the categories and reduced the number of levels to four. This is shown by the circles around the lexical categories in figure 34. Table 41 displays the final four lexical category groups that were used in the statistical analysis.
Figure 34: Mean F1 values for /e/ by lexical category

<table>
<thead>
<tr>
<th>Group</th>
<th>Lexical category (LC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>adjective, pronoun</td>
</tr>
<tr>
<td>2</td>
<td>clitic, noun, adverb, verb, determiner, interjection</td>
</tr>
<tr>
<td>3</td>
<td>preposition</td>
</tr>
<tr>
<td>4</td>
<td>conjunction</td>
</tr>
</tbody>
</table>

Table 41: Final lexical category groups for F1 analysis of /e/
Now that we have finished reviewing the grouping of levels within several of the independent variables for the analysis of the F1 for /e/, we can move on to the statistical results. As I have done with the previous analyses, the ranking of importance of the independent variables, as determined by the random forest, was used to determine the order in which the variables were added to the linear mixed effects model for the F1 dependent variable. This ranking is shown in figure 35, where the most important variables are listed first. Notice that the order of the variables differs from the DAPC for /e/ presented in figure 22. Here we see that the random forest suggests that the social variables are more important predictors than the linguistic variables. Each factor was added to the mixed effects linear model, using speaker as a random variable, in the order displayed in figure 35.
After a comparison of the models where I added each of the independent variables individually, and then comparing a second set of models using a series of ANOVAs with only the factors that improved the models, as I have done in previous analyses, I determined the best fit model for the analysis of F1 for /e/. Although social network has a high rank in the random forest, it was not chosen as part of the best fit model. The statistical model consisted of the following variables: distance (in syllables) away from the tonic vowel, word location within the utterance, gender, following sound (FS), and
lexical category (LC). I present the results from the statistical model in table 42, with the significant factor levels in bold. Note that a positive estimate value correlates with a higher F1 frequency and a negative estimate values correlates with a lower F1 frequency.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>8.94</td>
<td>0.14</td>
<td>62.51</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Distance (in syllables) away from the tonic vowel (reference level is ‘1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.31</td>
<td>0.14</td>
<td>2.24</td>
<td>0.03</td>
</tr>
<tr>
<td>Word location within the utterance (reference level is ‘utterance final’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within the utterance</td>
<td>0.20</td>
<td>0.07</td>
<td>2.95</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Gender (reference level is ‘female’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-0.70</td>
<td>0.16</td>
<td>-4.31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Following sound (reference level is ‘FS group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS group 2</td>
<td>0.06</td>
<td>0.06</td>
<td>0.97</td>
<td>0.33</td>
</tr>
<tr>
<td>FS group 3</td>
<td>0.25</td>
<td>0.10</td>
<td>2.50</td>
<td>0.01</td>
</tr>
<tr>
<td>Lexical category group (reference level is ‘LC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC group 2</td>
<td>0.22</td>
<td>0.08</td>
<td>2.67</td>
<td>0.01</td>
</tr>
<tr>
<td>LC group 3</td>
<td>0.86</td>
<td>0.18</td>
<td>4.76</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LC group 4</td>
<td>1.46</td>
<td>0.50</td>
<td>2.93</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Table 42: Factors that influence F1 frequency for /e/

Distance (in syllables) away from the tonic vowel is a significant factor for the analysis of F1 for /e/. Target vowels that are two syllables away from the tonic vowel have significantly higher F1 frequencies, i.e. lower articulations, than target vowels that are one syllable away. The results show that word location within the utterance is a
significant predictor of F1 values for /e/. There are significantly higher F1 values for
tokens within the utterance than in utterance final position. Since a lower F1 is an
indication of raising, these results coincide with the results for the DAPC that show more
raising in utterance final position. Just like we saw for the formant analyses for /o/, here
we see that males have significantly lower F1 frequencies than females, which may be
due to anatomical differences despite the vowel normalization procedure, and this will be
discussed in chapter 5.

For the following sound factor, we see that target vowels with a following dental
or labio-dental (FS group 3) have significantly higher F1 frequencies than target vowels
with a following palatal or no following sound (FS group 1). Note that for the DAPC we
also saw the most raising with a following palatal or no following sound, which is similar
to the results for F1. Changes to the reference level reveal that target vowels with a
following dental or labio-dental (FS group 3) also have significantly higher F1 values
than target vowels with a following velar, bilabial, or alveolar (FS group 2). There is no
significant difference between the following sound groups one and three. The general F1
frequency tendencies for the following sound variable are shown in table 43.

<table>
<thead>
<tr>
<th>Higher F1 (less raising)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dental, labio-dental (FS group 3)</td>
</tr>
<tr>
<td>velar, bilabial, alveolar (FS group 2)</td>
</tr>
<tr>
<td>palatal, no following sound (FS group 1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower F1 (more raising)</th>
</tr>
</thead>
</table>

Table 43: F1 frequency tendencies by following sound (FS) for /e/
In the lexical category variable, we see that when the target vowel is in lexical category two, three, or four (see table 41) it has a significantly higher F1 value than when it is in an adjective or pronoun (LC group 1). Remember that we also saw that pronouns and adjectives were in the group with the most raising for the DAPC. By changing the reference level, we can also determine that tokens in lexical category groups three and four have a significantly higher F1 value than tokens in lexical category group two. There are no other significant differences between the levels of the lexical category variable. The F1 frequency tendencies are shown in table 44.

<table>
<thead>
<tr>
<th>Higher F1 (less raising)</th>
</tr>
</thead>
<tbody>
<tr>
<td>conjunction (LC group 4)</td>
</tr>
<tr>
<td>preposition (LC group 3)</td>
</tr>
<tr>
<td>clitic, noun, adverb, verb,</td>
</tr>
<tr>
<td>determiner, interjection (LC</td>
</tr>
<tr>
<td>group 2)</td>
</tr>
<tr>
<td>adjective, pronoun (LC group</td>
</tr>
<tr>
<td>1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower F1 (more raising)</th>
</tr>
</thead>
</table>

Table 44: F1 frequency tendencies by lexical category (LC) for /e/

Now that I have finished presenting the results from the linear mixed effects model, I will present the interactions among the independent variables using the conditional inference tree for the analysis of F1 for /e/. I created the conditional inference tree as I did in the previous analyses, and I included only the significant factors in the same way as well. The conditional inference tree presented in figure 36 includes the following independent variables: gender, following sound (FS), word location within the utterance, lexical category (LC), and distance (in syllables) away from the tonic vowel.
The first things we notice in this conditional inference tree are that there are not as many interactions as in previous conditional inference trees for other dependent variables and that gender plays a role in the determination of the F1 value. We see that overall males have lower F1 frequencies than females. For females, the first interaction is with word location in the utterance. Target vowels in words in utterance final position generally have lower F1 frequencies, i.e. more raising, than target vowels in words within the utterance. For words within the utterance, the lexical category plays a role, and tokens

Figure 36: Conditional inference tree based on the F1 values for /e/
in lexical categories one and two have lower F1 frequencies than tokens in lexical categories three and four (see table 41). A discussion of the results for the F1 analysis for /e/ is presented in the chapter 5. I will now present the F2 analysis for /e/.

4.3.4.2 Continuous analysis of F2 values for /e/

Before presenting the results for the significance of the different independent factor groups, I will first describe how the levels within the previous consonant, following sound, lexical category, and previous vowel variables were grouped together.

Previous consonant grouping for F2 analysis of /e/

I used the same initial grouping method for the previous consonant variable that I used in previous analyses. I first took the individual sounds that I had coded separately and grouped them by point of articulation. This initial grouping was presented in table 26 in section 4.3.3.1. The initial seven groups were then organized by their mean F2 values in order to determine further grouping of the levels within the previous consonant factor. This is shown in figure 37, where we see the increasing normalized F2 values on the y-axis and the initial previous consonant groups by point of articulation on the x-axis. The circles indicate the groups that have been combined. The final three previous consonant levels used in the statistical model for F2 are presented in table 45.
Figure 37: Mean F2 values for /e/ by initial previous consonant group

<table>
<thead>
<tr>
<th>Group</th>
<th>Previous consonant (PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>consonant cluster with alveolar</td>
</tr>
<tr>
<td>2</td>
<td>alveolar, dental, bilabial, labio-dental, no previous consonant</td>
</tr>
<tr>
<td>3</td>
<td>velar, palatal, deleted previous consonant</td>
</tr>
</tbody>
</table>

Table 45: Final previous consonant groups for F2 analysis of /e/
Following sound grouping for F2 analysis of /e/

For the following sound factor, I originally coded for each individual sound. As explained in the previous sections, I then grouped the following sound based on point of articulation to reduce the number of factor levels. These groups can be reviewed in table 29 in section 4.3.3.1. Then the mean F2 value was calculated for each of the seven groups and the results were plotted to compare the levels. We see the comparison of the following sound groups by point of articulation and arranged by their mean F2 frequency in figure 38. The x-axis indicates the initial following sound group and the y-axis shows the normalized F2 values in order from lowest to highest. The seven initial following sound groups were reduced to three based on the mean F2 values. We see this grouping in figure 38 with the circles around the combined groups. The final levels for the following sound variable that were used for the statistical analysis for F2 of /e/ are presented in table 46.
Figure 38: Mean F2 values for /e/ by initial following sound group

<table>
<thead>
<tr>
<th>Group</th>
<th>Following sound (FS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bilabial, alveolar, dental, labio-dental</td>
</tr>
<tr>
<td>2</td>
<td>no following sound</td>
</tr>
<tr>
<td>3</td>
<td>velar, palatal</td>
</tr>
</tbody>
</table>

Table 46: Final following sound groups for F2 analysis of /e/
Lexical category grouping for F2 analysis of /e/

The lexical category variable for F2 of /e/ initially had twelve levels as described in previous sections. In order to reduce the number of levels, I first looked at the distribution of the average formant frequency for each category as I have done previously. In figure 39 we see the differences in mean formant values among the categories. Based on similar patterns in formant frequencies, I combined several of the categories and reduced the number of levels to three. This is shown by the circles around the groups in figure 39. Table 47 displays the final three lexical category groups that were used in the statistical analysis for F2 of /e/.
Figure 39: Mean F2 values for /e/ by lexical category

<table>
<thead>
<tr>
<th>Group</th>
<th>Lexical category (LC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>preposition</td>
</tr>
<tr>
<td>2</td>
<td>clitic, conjunction, noun, adjective, determiner, adverb</td>
</tr>
<tr>
<td>3</td>
<td>verb, pronoun, interjection</td>
</tr>
</tbody>
</table>

Table 47: Final lexical category groups for F2 analysis of /e/
Previous vowel grouping for F2 of /e/

The previous vowel variable refers to the vocoid before the target vowel. The original grouping of the previous vowel preceding the /e/ tokens for F2 can be seen in figure 40. Based on similar mean F2 values of the variants I was able to merge the 15 original previous vowel levels into five groups, which are indicated by the circles in the figure. Table 48 presents the final grouping of the previous vowel levels that was used in the statistical analysis for F2 of /e/.
Now that we have determined how the levels within several of the independent variables were combined, we can begin to review the results of the statistical analysis.
The ranking of importance of the variables, as determined by the random forest, was used to create the linear mixed effects model for the F2 dependent variable, as was done with the previous analyses. We can see this ranking in figure 41, where the most important variables are listed first. Note that the order of the variables differs from the DAPC for /e/ presented in figure 22. Here we see that the random forest suggests that the social variables are more important predictors than the linguistic variables. Each factor was added to the mixed effects linear model, using speaker as a random variable, in the order displayed in figure 41.
After creating different models by adding the independent variables individually, the models were compared using a series of ANOVAs. Then, using only the variables that significantly improved the models compared in the ANOVA, a second set of models was created and analyzed in the same way as in previous sections. The best fit model for F2 frequencies of /e/ included: social network, gender, previous vowel (PV), previous consonant (PC), following sound (FS), lexical category (LC), and number of syllables in the word. I present the results from the mixed effects linear model in table 49, where the
significant levels are in bold. Note that positive estimate values correlate with higher F2 values and negative estimate values correlate with lower F2 values.
<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>19.82</td>
<td>0.25</td>
<td>78.91</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Social network (reference level is ‘closed’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open</td>
<td>-0.58</td>
<td>0.21</td>
<td>-2.69</td>
<td>0.01</td>
</tr>
<tr>
<td>Gender (reference level is ‘female’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-0.86</td>
<td>0.16</td>
<td>-5.40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Previous vowel category (reference level is ‘PV group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV group 2</td>
<td>-0.02</td>
<td>0.13</td>
<td>-0.12</td>
<td>0.90</td>
</tr>
<tr>
<td>PV group 3</td>
<td>0.25</td>
<td>0.13</td>
<td>2.04</td>
<td>0.04</td>
</tr>
<tr>
<td>PV group 4</td>
<td>0.50</td>
<td>0.13</td>
<td>3.77</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PV group 5</td>
<td>0.95</td>
<td>0.35</td>
<td>2.76</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Previous consonant group (reference level is ‘PC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC group 2</td>
<td>0.65</td>
<td>0.12</td>
<td>5.54</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PC group 3</td>
<td>1.14</td>
<td>0.16</td>
<td>7.29</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Following sound group (reference level is ‘FS group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS group 2</td>
<td>0.49</td>
<td>0.07</td>
<td>7.58</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FS group 3</td>
<td>0.47</td>
<td>0.08</td>
<td>5.88</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lexical category (reference level is ‘LC group 1’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LC group 2</td>
<td>0.86</td>
<td>0.19</td>
<td>4.65</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LC group 3</td>
<td>1.01</td>
<td>0.19</td>
<td>5.35</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of syllables in the word (reference level is ‘2’)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 syllables</td>
<td>-0.14</td>
<td>0.07</td>
<td>-1.97</td>
<td>0.05</td>
</tr>
<tr>
<td>4 syllables</td>
<td>-0.09</td>
<td>0.10</td>
<td>-0.85</td>
<td>0.71</td>
</tr>
<tr>
<td>5 syllables</td>
<td>-1.27</td>
<td>0.31</td>
<td>-4.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6 syllables</td>
<td>-3.33</td>
<td>1.07</td>
<td>-3.12</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>7 syllables</td>
<td>0.38</td>
<td>1.07</td>
<td>0.35</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Table 49: Factors that influence F2 frequency for /e/
As the variable importance plot from the random forest predicted, the social variables are indeed significant in this model. The social network is significant for the first time for /e/ in this model. Members of the open social network have significantly lower F2 frequencies than members of the closed social network. Males have significantly lower F2 values, which indicates a more back articulation, than females.

For the previous vowel variable, we see that target vowels with a previous /o, e, we, j/ (PV group 3), or /je, aj, i/ (PV group 4), or /ej/ (PV group 5) have significantly higher F2 frequencies, i.e. a more fronted articulation, than target vowels with a previous /wa, wi, u, jo/ (PV group 1). By changing the reference level we notice that target vowels with a previous /o, e, we, j/ (PV group 3), or /je, aj, i/ (PV group 4), or /ej/ (PV group 5) also have a significantly higher F2 value than target vowels with a previous /ja, a, aw/ (PV group 2). Also, target vowels with a previous /je, aj, i/ (PV group 4) or /ej/ (PV group 5) have significantly higher F2 values than target vowels with a previous /o, e, we, j/ (PV group 3). There are no other significant differences between the previous vowel levels. The F2 tendencies for /e/ are shown in table 50.

<table>
<thead>
<tr>
<th>Higher F2 (more fronted)</th>
<th>Lower F2 (less fronted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/ej/ (PV group 5)</td>
<td>/ja, a, aw/ (PV group 2)</td>
</tr>
<tr>
<td>/je, aj, i/ (PV group 4)</td>
<td>/wa, wi, u, jo/ (PV group 1)</td>
</tr>
<tr>
<td>/o, e, we, j/ (PV group 3)</td>
<td>/o, e, we, j/ (PV group 3)</td>
</tr>
</tbody>
</table>

Table 50: F2 frequency tendencies by previous vowel (PV) for /e/
For the previous consonant variable, target vowels with a previous alveolar, dental, bilabial, labio-dental, or no previous consonant (PC group 2), and velars, palatals, and deleted previous consonants (PC group 3) have significantly higher F2 frequencies than target vowels with a previous consonant cluster with an alveolar (PC group 1). When I change the reference level, the results demonstrate that target vowels with previous velars, palatals, and deleted previous consonants have significantly higher F2 frequencies than target vowels with a previous alveolar, dental, bilabial, labio-dental, or no previous consonant. The three levels within the previous consonant group are significantly different from each other. The F2 tendencies for /e/ are shown in table 51.

<table>
<thead>
<tr>
<th>Higher F2 (more fronted)</th>
<th>Lower F2 (less fronted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>velar, palatal, deleted previous consonant (PC group 3)</td>
<td>previous consonant cluster with alveolar (PC group 1)</td>
</tr>
<tr>
<td>alveolar, dental, bilabial, labio-dental, no previous consonant (PC group 2)</td>
<td></td>
</tr>
</tbody>
</table>

Table 51: F2 frequency tendencies by previous consonant (PC) for /e/

For the following sound variable, we see that target vowels with no following sound (FS group 2) or a following palatal, or velar (FS group 3) have significantly higher F2 values than target vowels with following bilabial, labio-dental, dental, or alveolar (FS group 1). By changing the reference level, the results show that there are no significant differences between following sound groups two and three. However, I show the F2 tendencies for /e/ for the following sound variable in table 52.
In the lexical category variable, we see that the target vowels in verbs, pronouns, and interjections (LC group 3) and clitics, conjunctions, nouns, adjectives, determiners, and adverbs (LC group 2) have significantly higher F2 values than target vowels in prepositions (LC group 1). Changing the reference level shows that tokens in verbs, pronouns, and interjections have significantly higher F2 frequencies than tokens in clitics, conjunctions, nouns, adjectives, determiners, and adverbs. Therefore, all the levels within the lexical category variable are statistically different from each other. I show the order of the F2 tendencies for /e/ in table 53.

The variable for the number of syllables in the word has several significant levels. Target vowels in words with three, five or six syllables have significantly lower F2
frequencies than target vowels in words with two syllables. When I change the reference level, the results show that target vowels in words with five or six syllables have significantly lower F2 frequencies than target vowels in words with three or four syllables. Also, tokens in words with six syllables have significantly lower F2 frequencies than in words with two, three, fours, or seven syllables. There are no other significant differences between the levels in the number of syllables factor. I show the F2 tendencies for /e/ for this variable in table 54.

<table>
<thead>
<tr>
<th>Higher F2 (more fronted)</th>
<th>Lower F2 (less fronted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 54: F2 frequency tendencies by number of syllables for /e/

Now that I have finished presenting the results from the linear mixed effects model, I will now present the interactions among the independent variables using the conditional inference tree for the analysis of F2 for /e/. I created the conditional inference tree as I did in the previous analyses, including only the significant factors. The conditional inference tree presented in figure 42 includes the following independent variables: gender, social network, following sound (FS), lexical category (LC), previous vowel (PV), number of syllables in the word, and previous consonant (PC).
We can see that considering seven variables were added to the conditional inference tree, there are not too many interactions. The first division is gender and we see that males in the open social network have lower F2 frequencies than males in the closed social network. For the females, we see that following sound plays a role, and tokens in the following sound group two (see table 46) have lower F2 values than tokens in following sound groups one and three. Next we see an interaction with lexical category for following sound groups one and three. Tokens in lexical category group one (see table 47) have higher F2 frequencies than tokens in lexical category groups two and three. A discussion of the results for the F2 analysis for /e/ is presented in the following chapter.

Figure 42: Conditional inference tree based on the F2 values for /e/
In the last section of this chapter, I present a summary of the effects of the independent variables on all six dependent variables.

4.4 Summary

In this section I present summary charts of the results for the effects of the independent variables on all of the dependent variables. Overall, we see that the majority of the independent variables have an effect on at least one dependent variable. However, two of the linguistic variables, position of the vowel in the word and clitic or non-clitic, do not have a significant effect on any of the dependent variables. For the position of the vowel in the word, there are significantly less tokens in the non-final position than in the final position, and this is not surprising considering that the majority of words in Spanish have penultimate stress. Of the tokens in the non-final position, we can at least describe the general trends. For /e/, there is nearly an equal distribution of raised and non-raised tokens in the non-final position, with a slight tendency towards raising. This is what we would expect considering that we see more raising overall for /e/, but it would be interesting to see if this tendency changes with a higher token count. For /o/, there are fewer overall tokens in the non-final position, and the same general tendency for much less /o/ raising is seen in this position as well, where non-final tokens are not very likely to be raised. With the clitics we see a similar trend, i.e. clitics are much more likely to be raised than non-raised for /e/, and for /o/ the opposite is true. Again, this follows the general tendencies for /e/ and /o/. While these variables did not turn out to be significant in the statistical analyses, these tendencies confirm that these variables should be
considered when investigating post-tonic unstressed vowel raising, and future studies would benefit by including them in their analyses.

Apart from the two variables that I just discussed, all the other independent variables were significant for at least one dependent variable. We can see in table 55 that the previous consonant, following sound, and lexical category are the factors that affect the greatest number of dependent variables. On the other hand, the tonic vowel, previous vowel, stress pattern, and distance away from the tonic vowel are the factors that affect the least number of dependent variables. Note that table 55 is meant to be used for summary purposes only, and should be considered in conjunction with the results presented in this chapter.

<table>
<thead>
<tr>
<th>Significant factors</th>
<th>/o/</th>
<th>/e/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DAPC</td>
<td>F1</td>
</tr>
<tr>
<td>Word location within the utterance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Previous consonant (PC)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Type of syllable</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lexical category (LC)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tonic vowel (TV)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Social network</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Following sound (FS)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Stress pattern</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Number of syllables in the word</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Distance (in syllables) away from the tonic vowel</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Previous vowel (PV)</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 55: Summary of the independent variables that are significant for each dependent variable
The following tables, 56-61, show the direction of the effect of the significant variables for each of the dependent variables. For the DAPC summary for /o/ and /e/, tables 56 and 57, the levels within each significant independent variable are listed from the most to the least amount of raising. For the formant analyses, tables 58-61, the significant independent variables are listed from the highest to lowest formant frequencies. Note that these summary tables are meant to be used as a quick reference to the overall results in this chapter, but they do not show which levels are significantly different from each other. Refer back to the corresponding sections for a more detailed description of the statistical significance of the results. Also note that overall, the conditional inference trees support the general results for each dependent variable. In the following chapter I present a discussion and interpretation of the results.

<table>
<thead>
<tr>
<th><strong>DAPC /o/</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Word location within the utterance</strong></td>
<td>utterance final &gt; within the utterance</td>
</tr>
<tr>
<td><strong>Previous consonant (PC)</strong></td>
<td>no previous consonant (PC group 1) &gt; palatal ((PC group 2) &gt; bilabial and labio-dental (PC group 3) &gt; dental and alveolar (PC group 4) &gt; velar and consonant cluster with alveolar (PC group 5) &gt; deleted previous consonant (PC group 6)</td>
</tr>
<tr>
<td><strong>Type of syllable</strong></td>
<td>closed &gt; open</td>
</tr>
<tr>
<td><strong>Lexical category</strong></td>
<td>pronoun (LC group 1) &gt; adjective, noun, verb (LC group 2) &gt; preposition, adverb, determiner, clitic (LC group 3) &gt; conjunction (LC group 4) &gt; possessive pronoun, interjection (LC group 5)</td>
</tr>
<tr>
<td><strong>Tonic vowel (TV)</strong></td>
<td>/u, aj, ja/ (TV group 1) &gt; /wi, i, a, je, e, o/ (TV group 2) &gt; /wa, we/ (TV group 3) &gt; /jo, iw, ej/ (TV group 4)</td>
</tr>
<tr>
<td><strong>Social network</strong></td>
<td>closed &gt; open</td>
</tr>
</tbody>
</table>

Table 56: Summary of effects of significant independent variables on the DAPC for /o/
**DAPC /e/**

<table>
<thead>
<tr>
<th>Previous consonant (PC)</th>
<th>palatal (PC group 1) &gt; alveolar, dental, velar (PC group 2) &gt; bilabial and labio-dental (PC group 3) &gt; no previous consonant (PC group 5) &gt; consonant cluster with alveolar (PC group 4) &gt; deleted previous consonant (PC group 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexical category (LC)</td>
<td>adjective, clitic, determiner, interjection, noun, pronoun, verb, adverb (LC group 1) &gt; conjunction (LC group 2) &gt; preposition (LC group 3)</td>
</tr>
<tr>
<td>Following sound (FS)</td>
<td>bilabial, palatal, velar, no following sound (FS group 1) &gt; dental, alveolar (FS group 2) &gt; labio-dental (FS group 3)</td>
</tr>
<tr>
<td>Stress pattern</td>
<td>penultimate &gt; antepenultimate</td>
</tr>
</tbody>
</table>

Table 57: Summary of effects of significant independent variables on the DAPC for /e/.

---

**F1 frequency for /o/**

<table>
<thead>
<tr>
<th>Word location within the utterance</th>
<th>within the utterance &gt; utterance final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous consonant (PC)</td>
<td>deleted previous consonant (PC group 4) &gt; alveolar, dental (PC group 3) &gt; velar (PC group 2) &gt; no previous consonant, palatal, bilabial, labio-dental, consonant cluster with alveolar (PC group 1)</td>
</tr>
<tr>
<td>Type of syllable</td>
<td>open &gt; closed</td>
</tr>
<tr>
<td>Lexical category</td>
<td>conjunction (LC group 3) &gt; adjective, noun, verb, adverb, clitic, preposition (LC group 2) &gt; possessive pronoun, interjection, determiner, pronoun (LC group 1)</td>
</tr>
<tr>
<td>Following sound (FS)</td>
<td>alveolar (FS group 2) &gt; bilabial, velar, dental, palatal (FS group 3) &gt; no following sound, labio-dental (FS group 1)</td>
</tr>
<tr>
<td>Gender</td>
<td>female &gt; male</td>
</tr>
</tbody>
</table>

Table 58: Summary of effects of significant independent variables on F1 for /o/.
### F2 frequency for /o/

<table>
<thead>
<tr>
<th><strong>Type of syllable</strong></th>
<th>closed &gt; open</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Following sound (FS)</strong></td>
<td>palatal (FS group 3) &gt; alveolar, dental (FS group 2) &gt; bilabial, velar, labio-dental, no following sound (FS group 1)</td>
</tr>
<tr>
<td><strong>Previous consonant (PC)</strong></td>
<td>no previous consonant, palatal (PC group 3) &gt; alveolar, dental, consonant cluster with alveolar, deleted previous consonant (PC group 2) &gt; bilabial, velar (PC group 1)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>female &gt; male</td>
</tr>
</tbody>
</table>

Table 59: Summary of effects of significant independent variables on F2 for /o/

### F1 frequency for /e/

<table>
<thead>
<tr>
<th><strong>Following sound (FS)</strong></th>
<th>dental, labio-dental (FS group 3) &gt; velar, bilabial, alveolar (FS group 2) &gt; palatal, no following sound (FS group 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lexical category (LC)</strong></td>
<td>conjunction (LC group 4) &gt; preposition (LC group 3) &gt; clitic, noun, adverb, verb, determiner, interjection (LC group 2) &gt; adjective, pronoun (LC group 1)</td>
</tr>
<tr>
<td><strong>Distance (in syllables) away from the tonic vowel</strong></td>
<td>2 &gt; 1</td>
</tr>
<tr>
<td><strong>Word location within the utterance</strong></td>
<td>within the utterance &gt; utterance final</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>female &gt; male</td>
</tr>
</tbody>
</table>

Table 60: Summary of effects of significant independent variables on F1 for /e/
### F2 frequency for /e/

<table>
<thead>
<tr>
<th>Social network</th>
<th>Closed &gt; Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous vowel (PV)</td>
<td>/ej/ (PV group 5) &gt; /je, aj, i/ (PV group 4) &gt; /o, e, we, j/ (PV group 3) &gt; /wa, wi, u, jo/ (PV group 1) &gt; /ja, a, aw/ (PV group 2)</td>
</tr>
<tr>
<td>Previous consonant (PC)</td>
<td>Velar, palatal, deleted previous consonant (PC group 3) &gt; Alveolar, dental, bilabial, labio-dentals, no previous consonant (PC group 2) &gt; Consonant cluster with alveolar (PC group 1)</td>
</tr>
<tr>
<td>Following sound (FS)</td>
<td>No following sound (FS group 2) &gt; Velar, palatal (FS group 3) &gt; Alveolar, dental, bilabial, labio-dental, (FS group 1)</td>
</tr>
<tr>
<td>Lexical category (LC)</td>
<td>Preposition (LC group 3) &gt; Clitic, conjunction, noun, adjective, determiner, adverb, (LC group 2) &gt; Verb, pronoun, interjection (LC group 1)</td>
</tr>
<tr>
<td>Number of syllables</td>
<td>7 &gt; 2 &gt; 4 &gt; 3 &gt; 5 &gt; 6</td>
</tr>
<tr>
<td>Gender</td>
<td>Female &gt; Male</td>
</tr>
</tbody>
</table>

Table 61: Summary of effects of significant independent variables on F2 for /e/
Chapter 5. Discussion

In this chapter, I present a discussion of the statistical results presented in chapter 4, reviewing each independent factor individually. In section 5.1, I present the overall patterns that we see in the results, with a specific emphasis on the differences between /o/ and /e/, and on the behavior of F2. In the following section, 5.2, I discuss the effect of the social factors on the raised or non-raised distinction and on the frequency of F1 and F2. I then consider the influence of the linguistic variables on both the categorical raised or non-raised distinction and the continuous values of the first two formants in section 5.3. The final section, 5.4, presents the theoretical implications of the interpretation of the results.

5.1 Overall patterns in the results

In chapter 4, the results show that /o/ and /e/ tokens behave very differently, with significantly more /e/ raising than /o/ raising. This is especially intriguing considering that in Puerto Rico and Spain we see different trends, i.e. much more /o/ raising (Navarro Tomás 1948, Holmquist 1998, 2005, Oliver Rajan 2008). The two mid vowels are influenced by the same independent variables in some cases, such as previous consonant or following sound. However, for each dependent variable, except the F2 frequency for
/e/, we see that /o/ raising or changes in /o/ formant values are affected by more independent variables than /e/. We can see this pattern quite clearly in summary table 55 at the end of chapter 4. For example, the DAPC for /o/ has six significant variables and the DAPC for /e/ has four. Since /e/ raising occurs more frequently overall, I propose that the raising process is more phonologized (see Hyman 1975 and Blevins 2004 for more on phonologization) for /e/, and as a result it is less influenced by the independent variables. This means that the raising of /e/ is in a more advanced state, where there is less phonetic variation and the change is more categorical. I come back to this point in section 5.4, where I discuss possible explanations for this difference in behavior between /e/ and /o/.

To summarize, we have seen that raising of /e/ is more likely to occur, and it is not as dependent on the effects of the independent variables.

The factors that trigger more raising of the mid vowels in the categorical analysis are the same factors that correlate with lower F1 frequencies, i.e. a higher articulation in the vowel in the vocal tract, as we would expect. However, the differences in F2 merit attention, especially for /o/, since the behavior of this formant is less straightforward than that of F1. For both /o/ and /e/ the factors that correlate with higher F2 values tend to coincide with the factors that trigger more raising in the categorical analysis. For /e/, higher F2 values indicate a more fronted articulation, and along with the lowering of F1, this makes the target vowel more similar to its high counterpart, /i/. Meanwhile for /o/, higher F2 values also indicate a more fronted articulation, which is unexpected given that descriptions of the Spanish vowel system indicate that /u/ is articulated more towards the back of the vocal tract than /o/. Thus, for /o/, in the contexts where we see raising there
are similarities with /u/ in the F1 dimension, but not for F2. We would anticipate lower F2 values for /u/ since this is a trend that we see cross-linguistically and in Spanish (see chapter 2), although this would have to be corroborated with evidence from this variety. Thus, the results seem to indicate that a raised /o/ has a higher F2 frequency than an underlying high, back vowel, /u/. This suggests that F1 plays a larger role in determining raising and perhaps the higher F2 frequencies are what distinguish a raised /o/ from an underlying /u/. See section 4.1.2.1 where I present the statistical differences in formant values, and we see that raised /o/ tokens have higher F2 values than non-raised tokens. In summary, the results show a clear pattern in the direction of change in formant values, with lower F1 and higher F2 values indicating raising for both mid vowels. Now that we have reviewed the overall tendencies from the results, I will begin a discussion of the interpretation of the results for the social and linguistic factors.

5.2 Social factors

Since many of the social factors are correlated for the members of the Colongo community, as discussed in section 3.4.2.2, only social network and gender were considered for the statistical models. Social network is a significant predictor for two of the six dependent variables and gender is a significant indicator for four of the six (see summary table 55 at the end of chapter 4). The discussion of the effect of these two independent variables follows below.
5.2.1 Social network

Social network plays a significant role for raising of /o/, but not for /e/ in the DAPC. For the categorical analysis of /o/, we see more raising in the closed social network than in the open social network. In the analysis of F2 frequency for /e/ we see higher F2 frequencies in the closed social network. This indicates that the target vowel is being pronounced in a more fronted articulation in the mouth, more similarly to the high, front vowel /i/. Higher F2 frequencies of /e/ by members of the closed network, those who we would expect to have more raising, could be an indication that in addition to undergoing raising, the target vowels are being fronted as well.

As we saw in section 2.5, previous literature on social networks (Milroy 1987, Milroy and Gordon 1987, Holmquist 1998, among others) has shown that members of a more closed social network are more likely to maintain local linguistic norms. Raising could be considered a local linguistic norm since it has yet to be documented in other varieties of Mexican Spanish outside of the vicinity of Michoacán and nearby states. In Colongo, the speakers in the closed network have had little exposure to other dialects of Mexican Spanish and may not be aware of the possible social stigma associated with vowel raising. This is not to say that they are not aware that they have a particular way of speaking. When I inquired about why a few words with raising, such as once ‘eleven’ or grande ‘big’, are pronounced differently in Colongo, one of my participants (P1) told me, “Así hablamos en Colongo. Es más rápido” ‘That’s the way we speak in Colongo. It’s faster’. Her reaction suggests that although the members of the community have heard
more ‘standard’ varieties of Spanish, through school, television, etc., there is a certain way that one speaks in Colongo. I suggest that the local linguistic norms comprise part of the Colongo identity.

The speakers from the open network, on the other hand, have had more exposure to other dialects of Spanish through their encounters in the United States with speakers from other regions in Mexico and other Spanish-speaking countries. They have spent several years in the United States and may have even consciously changed the amount of vowel raising in their speech to blend in with the other Spanish varieties. Although I do not have data for my participants from their time away from Colongo, I did work for several years with one of the speakers (P10) in the United States and did not notice any vowel raising in his pronunciation of Spanish. Yet, when I was in Colongo interviewing him many years later, I could not believe that there was evidence of vowel raising in his speech, considering that I had never heard it when we were working together. One hypothesis for this change is that incorporating vowel raising into his speech could be a way of reasserting his Colongo identity after having been away for so many years.

Another possibility is that this is an example of dialectal accommodation. According to speech accommodation theory (see Trudgill 1986, Giles, Coupland and Coupland 1991, among others), speakers may speak in a way that is similar to others around them in order to fit in, show solidarity, etc. (Kerswill 2002).

Thus, I propose that mobility plays an important role in the vowel raising patterns in Colongo, just as it did in the Puerto Rican communities investigated by Holmquist (1998, 2005) and Oliver Rajan (2007, 2008), where speakers with less mobility have
more raised vowels than those with more mobility. Mobility is reflected in the social networks in the current analysis.\textsuperscript{16} I included the time spent in and away from Colongo, which are direct measures of mobility, as factors in the determination of the social networks. The other two factors used to determine the networks, education and occupation, also relate to mobility. More education indicates that the participant had to leave the Colongo community, and therefore has more mobility, since only the primary school is located in Colongo. Occupation reflects mobility as well, and the participants who work in the fields or even further away in Zamora have increasing mobility and interactions with people from outside of Colongo.

Members of the open network may or may not have altered their speech while they were outside of Colongo. In the case of P10, it seems that he did change the way he spoke while in the United States. Yet, as the members of the open network are re-integrated into the Colongo community, there is still evidence of vowel raising in their speech. We have seen that there is no significant difference in the raising of /e/ between the closed and open network in the DAPC (in the chi-square test, $p = 0.20$), but the tendency is that the speakers from the open network have less raising. We can see this raising tendency in figure 43, where the x-axis shows the two network groups. Note that the closed network represents a larger part of the figure, which indicates the greater

\begin{footnotesize}
\textsuperscript{16} As I mentioned in footnote 12 in chapter 3, I did examine mobility as its own independent social factor, both as a continuous and a categorical variable, but on its own mobility did not turn out to be a significant predictor of raising.
\end{footnotesize}
number of members. However, a significant difference exists for /o/, which is raised less than /e/ in general, and speakers from the open network have much less raising than speakers from the closed network. Refer back to figure 17 in chapter 4 for a visual representation of this difference. Members of the closed network have higher rates of both /e/ and /o/ raising, which sets them apart from the members of the open network. I propose that the difference in raising is due to the mobility of the members of the open network and the outside influences they have encountered. The speakers from the open network do still have a noticeable amount of vowel raising in their speech, which could be considered as a way to show their Colongo identity.
In addition to the DAPC analysis of /o/, social network is also a significant predictor of F2 for /e/. The members of the open social network have significantly lower F2 frequencies than members of the closed social network. This means that the speakers from the closed network produce the mid vowel /e/ in a more fronted position of the mouth than the speakers from the open network. Interestingly, social network is not an important predictor of F1 for either mid vowel although the first formant corresponds with tongue height, which we associate with raising. It is harder to conclude that the

Figure 43: Percentage of /e/ raising by social network
effect on F2 correlates with more or less raising, since F1 is the acoustic parameter that best represents vowel height.

It is important to note that the closed network has 26 members and the open network has only five (see section 3.4.2.2.1). The distribution of the participants may be part of the reason why the social network is significant for only two of the six dependent variables. In fact, originally I intended to leave the social network as a continuous variable, using the numerical scale that I presented in chapter 3, but social network did not turn out to be a significant indicator of raising when analyzed continuously. Again, I suspect that the low number of participants in this study who have left the community affected the results, and future studies with a more equally distributed population may have different results (see section 6.3).

5.2.2 Gender

Gender is a significant predictor only for the continuous analysis of the first and second formant values, but not for the DAPC. For both mid vowels, and for both F1 and F2, males have significantly lower formant frequencies than females. Thus, the male speakers are producing mid vowels in a higher space and more towards the back of the mouth than the females. The higher articulation of the mid vowels could be an indication of raising. However, previous literature on vowel production and perception has shown differences in formant frequencies based on gender, more precisely that men tend to have lower formant values than women. For example, Martínez Celdrán and Fernández Planas (2007) found that women tend to have higher formant values than men in Spanish and
they attribute this difference to the shorter length of the vocal tract of women. Similar results have been found in other languages (see Hillenbrand et al. 1995 for American English, Kant 1970 for Russian, and Pepiot 2012 for French) indicating that gender differences in vowel production is a trend that we see cross-linguistically. Hillenbrand et al. (1995) conducted a perception study where they altered formant values, along with the fundamental frequency, and found that changes in formant frequency had an effect on whether the participants perceived voices as male or female, where lower formants indicated a male voice. Therefore, despite the efforts to avoid gender differences through the vowel normalization procedure, it seems that in addition to the raising hypothesis there is a possibility that the differences in formant frequencies can be attributed to anatomical differences. As I mentioned in the beginning of this section, there were not significant differences in gender for either mid vowel based on the DAPC which uses the F1 and F2 values in the raised and non-raised distinction. This evidence suggests that both raised and non-raised tokens have lower formant values for males overall and that the effect of gender in the formant analyses may be due to anatomical differences, rather than an indication of raising. Future research should consider the gender-based formant differences since it is hard to tease apart the raising from anatomical differences.

5.3 Linguistic factors

Through the use of statistical analyses using mixed effects models, I have determined the independent factors that have a significant effect on the dependent variables. In the sections that follow, I present a discussion focusing on the interpretation
of the impact on the categorical (DAPC) and continuous (F1 and F2) dependent variables by the following independent linguistic factors: word location within the utterance, type of syllable, previous consonant, following sound, stress pattern, distance (in syllables) away from the tonic vowel, tonic vowel and previous vowel, number of syllables in the word, and lexical category.

5.3.1 Word location within the utterance

Word location in the utterance plays a significant role in the DAPC for /o/ and F1 for both /o/ and /e/. Target vowels in words in utterance final position are significantly more likely to be raised than when they are located in words within the utterance for /o/. We can see the distribution of the raw DAPC data for the word location within the utterance in table 62. Remember that for /o/ the overall percentage of raising is not very high. We can see more raising in the utterance final position for both /o/ and /e/, even though there is a greater raw token count found within the utterance. Although the difference between word locations is not significant for /e/, we can see that the trend, although slight, is similar.

<table>
<thead>
<tr>
<th></th>
<th>/o/</th>
<th></th>
<th>/e/</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-raised</td>
<td>Raised</td>
<td>Total N</td>
<td>Non-raised</td>
</tr>
<tr>
<td><strong>Utterance final</strong></td>
<td>449   (79%)</td>
<td>121 (21%)</td>
<td>570</td>
<td>69  (20%)</td>
</tr>
<tr>
<td><strong>Within the utterance</strong></td>
<td>1998 (90%)</td>
<td>223 (10%)</td>
<td>2221</td>
<td>343 (24%)</td>
</tr>
</tbody>
</table>

Table 62: Distribution of tokens for word location within the utterance for DAPC
As for the F1 frequency, both mid vowels have a lower F1 value when they are located in a word in utterance final position than in words within the utterance. The lower F1 frequency corresponds to a higher articulation in the vocal tract and this coincides with the tendencies we see in table 62 for the DAPC. Summarizing, there is more raising utterance-finally than medially, both for the continuous and categorical raising variables.

In line with these results, several studies have reported a different behavior of vowels in utterance final positions in comparison with medial positions. For example, Meyer and Hansen (2007) discuss how many languages, including English, Spanish, and French, have evidence of utterance final devoicing. Shadle (1997) attributes utterance final devoicing to the opening of the glottis in preparation for a pause. Meyer and Hansen see vowel length neutralization in Finnish, a language with phonemic contrasts in vowel length, in utterance final position as a side effect of devoicing. The results of their perception experiments, where listeners more frequently identified devoiced vowels as being short rather than long, confirm this hypothesis. One explanation is that in utterance final position the perceptual cues to distinguish between phonemic long and short vowels are more difficult to identify due to the devoicing, and therefore vowel neutralization occurs (Steriade, 1995, 1997). According to this explanation, the difficulty of perceiving the phonemic length contrast utterance-finally would lead the speakers to also lose the contrast in their production in this position. So, a perceptual difficulty leads to neutralization in production.

In section 2.3.1.1 I discussed how devoicing is a prevalent feature in Mexican Spanish (Boyd-Bowman 1952, Canellada de Zamora and Zamora Vicente 1960, among others).
others. Delforge (2008a) found more devoicing in Andean Spanish at the end of larger prosodic domains than at word boundaries, which indicates more devoicing utterance-finally than medially. One of the claims of this dissertation is that vowel raising can be seen alongside devoicing as another type of vowel weakening process (see chapter 2), and therefore I would expect more raising of vowels in the same position. Since more raising occurs in utterance final position, where we also see more devoicing, this supports my Weakening Hypothesis. Furthermore, the higher degree of occurrence of raising in the utterance final position leads to more frequent neutralization of vowel contrasts in this location so that /e/ and /i/ are produced the same as are /o/ and /u/. This is similar to what Meyer and Hansen found in terms of vowel length neutralization, only that here we observe neutralization of vowel quality.

5.3.2 Type of syllable

The type of syllable, open or closed, is only significant for /o/, for all three dependent variables, but not for /e/. We see more raising in closed syllables in the DAPC for /o/. Lower F1 frequencies in closed syllables is another indication that this is a context where raising occurs more frequently, based on the higher articulation of the tongue in the vocal tract. For F2 we see higher frequencies in closed syllables, which indicates that the tokens are being produced more towards the front of the mouth. Cross-linguistically, vowel duration has been found to be reduced in closed syllables compared to open syllables (see Maddieson 1985 for a cross-linguistic perspective and for Spanish see Navarro Tomás 1917, Lehiste 1970, Borzone de Manrique & Signorini 1983, and
Almeida 1986), and it is precisely in the former context that we find more raising. I argue that this finding supports my Weakening Hypothesis since we observe that raising is more likely to occur in an environment where reduction is present, in this case a reduction in vowel duration. However, the trend of the F2 frequency is not in the same direction as it would be for a high vowel, which suggests that although the raised vowels are similar to their high counterparts, the difference still exists between a raised /o/ and an underlying /u/. See section 5.1 for a discussion of the special behavior of F2. There is no effect of type of syllable on any of the /e/ variables, further supporting the claim that vowel raising is in a much more advanced stage for this vowel than for /o/, and consequently it is less sensitive to the influence of external and internal factors. This means that /e/ raising is very likely to take place regardless of conditionings such as syllable type (see section 5.1).

5.3.3 Previous consonant

Previous consonant significantly influences five of the dependent variables, i.e. the DAPC and F2 analyses for /o/ and /e/ and the F1 analysis of /o/. In the DAPC for /o/, target vowels with a previous palatal are raised significantly more than target vowels with any other previous consonant. In order to produce the palatal consonants, the tongue body moves up to touch the hard palate, which leaves the tongue in a higher position directly before the articulation of the target vowel, which uses the same articulator, i.e. the tongue body. We can also consider that palatales are produced with a more fronted tongue body position, when compared to velars, for example, and this explains why we tend to see
higher F2 frequencies after the palatal consonants. In summary, potential interactions are greater with consonants articulated with the tongue body, since this is the articulator that is used to produce the vowels as well. This suggests that coarticulatory effects play a role in the raised or non-raised distinction as the higher and more fronted articulation of the previous consonant influences the articulation of the target vowel. It should be noted, though, that coarticulation is not the only reason there is raising, and I will return to this point at the end of this section as well as in section 5.4. For the DAPC for /e/, target vowels with a previous palatal are the most frequently raised group, although only the difference between the palatals and previous consonant clusters ending in alveolar is statistically significant. This indicates that the coarticulatory effect of the palatals is greater and this can be explained because the palatal consonants are produced using the same articulator that is used for the target vowel, the tongue body, whereas the alveolar consonants are articulated with the tongue tip. For both the first and second formant values for /o/ and for the second formant for /e/, we see similar trends as we did with the DAPC. We see that target vowels with previous palatals have lower F1 frequencies for /o/ and higher F2 frequencies for both /o/ and /e/. Again, the higher and more fronted articulation of the palatal leads the articulation to a higher position, i.e. lower F1 values, and a more fronted position, i.e. higher F2 values. Similar to the current results, Navarro Tomás (1948), and Holmquist (1998, 2005) found that target vowels with a previous palatal are the most likely to be raised.

The only time there is more raising for /o/ than with a preceding palatal is when there is no previous consonant. When there is no previous consonant, this indicates that
/o/ is part of a diphthong and preceded by a glide, such as *ejercicio* ‘exercise’, or is part of a hiatus and preceded by a tonic high vowel, such as *tío* ‘uncle’, or a non-high vowel, such as *veo* ‘I see’. While the amount of raising is not significantly different between tokens without a previous consonant and tokens with a previous palatal, the higher trend in raising of the former may be due to a coarticulatory effect of the adjacent previous vowel. In the majority of the cases where there is no previous consonant, there is a high vowel directly before the target vowel (see section 5.3.7 for more on the previous vowel variable). Thus, although the previous vowel was not found to be significant in the statistical model, it could be playing a role in the DAPC tokens for /o/ with no previous consonant where this vowel is right next to the target one. In my results, tokens with no previous consonant were raised the most for the DAPC for /o/, but tokens with no previous consonant were much less likely to be raised for the DAPC for /e/. The tokens for /e/ with no previous consonant are preceded by a glide, such as *ensucien* ‘they get [something] dirty’. In this case, if there were raising of the target vowel then the two vowels would be the same, which could be why we see less raising. Yet, since we see less overall raising for the DAPC for /e/ when there is no previous consonant, this could be further evidence that /e/ is less affected by other independent factors, such as coarticulation. Oliver Rajan (2008) found a tendency for tokens with no previous consonant or a deleted previous consonant to be the ones with the highest amount of raising. However, I found that tokens with a deleted consonant, for the DAPC for both /e/ and /o/, were the least likely to be raised. Similar to Oliver Rajan’s data, the majority of the deleted previous consonants are participles, such as *tomar* ‘taken’, where the /d/ is
deleted, although for /e/ an example is sa[b]es ‘you know’. Although my findings are different from Oliver Rajan’s, they are not surprising since the tonic vowel tends to be a low vowel in many of the cases where there is a deleted preceding consonant, and this low tonic vowel would exert less coarticulatory pressure towards raising.

As I have mentioned above, coarticulation may be playing a role in vowel raising, especially when the previous consonant is a palatal. The possibility for interactions increases due to the use of the same articulator, the tongue body, for both the palatal consonants and the vowels. As a result of the coarticulation with the adjacent consonants, the articulation of the vowel can be reduced in duration (Lindblom 1963). Similar results are found by Browman and Goldstein (1992) who show that there can be overlap in the consonant and vowel gestures, especially when they use the same articulator, which results in a reduced vowel gesture. The correlation between coarticulation and reduction could lend some support to the Weakening Hypothesis since we see more raising in contexts that are reduced by coarticulation (Flemming 2004). But, note that coarticulation is not the only factor that contributes to vowel raising.

5.3.4 Following sound

This is one of the first studies, along with Barnes (2013), to look at the following sound and its effect on vowel raising. Since previous studies have found coarticulatory effects from the previous consonant it is feasible that we would also find these effects from the following sound, given that vowels are coarticulated with both preceding and following sounds. For the DAPC for /e/ we see that the group with
following palatals is raised more frequently than other groups. This is what we would expect to find considering we see more raising with a previous palatal as well. For the F1 frequency of /e/ we find that target vowels with a following palatal have a lower F1 value. It appears that coarticulation plays a role and the higher articulation of the palatal influences the articulation of F1 for /e/. For F2 of /e/ the target vowels before palatals have statistically higher frequencies, i.e. a more fronted articulation, than those before alveolars, dentals, bilabials and labio-dentals. The more fronted articulation could be a result of anticipatory coarticulation of the target vowel with the following palatal, both of which are articulated with the tongue body (see section 5.3.3).

Only the target vowels with no following sound have higher F2 values than target vowels with following palatals for /e/. This could be because tokens with no following sound are either before a pause or in utterance final position, virtually all of which are utterance final, and we have already discussed how utterance final position leads to more raising (section 5.3.1). For /o/ we see that no following sound corresponds with the lowest F1 values. However, the F2 values of /o/ are highest with a following palatal, which suggests a more fronted articulation. As I have mentioned previously, we see that the higher F2 values for /o/ typically correlate with raising (see section 5.1).

5.3.5 Stress pattern

The results show that stress pattern is a significant predictor of raising for the DAPC for /e/. We see significantly more raising when there is penultimate stress than when there is antepenultimate stress, illustrated in table 63 below. If we look at the raw
token counts for /o/ for the DAPC, we can see a slight trend towards more raising when there is penultimate stress. The results suggest that in general, a closer proximity of the target vowel to the tonic syllable leads to more raising, since a target vowel in a word with penultimate stress is in the syllable directly adjacent to the tonic syllable, i.e. in post-tonic position. On the other hand, a target vowel in a word with antepenultimate stress could either be in the post-tonic position or final position, which is not in direct contact with the stressed syllable. In my data, target vowels in words with antepenultimate stress tend to be in the final syllable rather than in the post-tonic position, as shown in table 64, and therefore there is at least one syllable in between them and the tonic position. Several studies have identified the post-tonic position as an articulatorily weak position, with the highest amount of reduction or weakening (see Arvaniti 1991, de Jong 1998, Cole et al. 1999, and Campos-Astorkiza (forthcoming)). More raising in this weak post-tonic position for the DAPC for /e/ supports my Weakening Hypothesis. This contrasts with the findings of Oliver Rajan (2008) who found more raising in antepenultimate syllables for both /o/ and /e/ and no significant difference, in regard to stress pattern, between the mid vowels. The current results suggest that stress pattern plays a different role in vowel raising in Colongo, where there is more raising in penultimate syllables.
<table>
<thead>
<tr>
<th></th>
<th>/o/</th>
<th>/e/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-raised</td>
<td>Raised</td>
</tr>
<tr>
<td>Antepenultimate</td>
<td>100 (90%)</td>
<td>15 (10%)</td>
</tr>
<tr>
<td>Penultimate</td>
<td>2347 (88%)</td>
<td>329 (12%)</td>
</tr>
</tbody>
</table>

Table 63: Distribution of tokens for stress pattern for DAPC

<table>
<thead>
<tr>
<th></th>
<th>/o/</th>
<th>/e/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Final</td>
<td>Non-final</td>
</tr>
<tr>
<td>Antepenultimate</td>
<td>95 (83%)</td>
<td>20 (17%)</td>
</tr>
</tbody>
</table>

Table 64: Distribution of tokens for stress pattern by the position of the vowel within the word

5.3.6 Distance (in syllables) away from the tonic vowel

Distance (in syllables) away from the tonic vowel is only a significant predictor of F1 frequency for /e/. In the results chapter we saw lower F1 values, i.e. a more raised articulation, in target vowels that were one syllable away from the tonic vowel when compared to target vowels that were two syllables away from the tonic vowel. In table 65 we can see the distribution of raw tokens for the DAPC for both mid vowels. In this table we see a tendency for more raising of /e/ when the target vowel is one syllable away from the tonic vowel, as opposed to two syllables away. Although this difference is not statistically significant, the DAPC results for /e/ correlate with the statistically lower F1 values for this vowel when the distance from the tonic vowel is shorter. Additionally, the raising tendency for /e/ in terms of syllables away from the tonic vowel supports the idea
discussed in 5.3.5 that the closer the target vowel is to the tonic syllable, specifically in the post-tonic position, the more likely there will be raising.

However, for /o/ we see a somewhat different behavior. The DAPC results for /o/ (in table 65) show that raising is slightly more likely when the target vowel is two syllables away from the tonic vowel, which is the opposite of what we see for /e/, although this trend for /o/ is not statistically significant. The results for distance from the tonic syllable show that more distance from the tonic syllable slightly favors raising. In summary, the general trends for the mid vowels are distinct, with more raising when the target vowel is closer to the tonic syllable for /e/, and more raising when the target vowel is further from the tonic syllable for /o/. This is the first time that the results for the DAPC point in opposite directions for the mid vowels, however note that these results are only significant for the F1 frequency for /e/.

<table>
<thead>
<tr>
<th></th>
<th>/o/</th>
<th>/e/</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-raised</td>
<td>Raised</td>
<td>Total N</td>
</tr>
<tr>
<td>1 syllable away</td>
<td>2365 (88%)</td>
<td>330 (12%)</td>
<td>2695</td>
</tr>
<tr>
<td>2 syllables away</td>
<td>82 (85%)</td>
<td>14 (15%)</td>
<td>96</td>
</tr>
</tbody>
</table>

Table 65: Distribution of tokens for distance (in syllables) away from the tonic vowel for DAPC
5.3.7 Tonic vowel and previous vowel

The tonic vowel refers to the vowel or diphthong that carries the stress in the word and this can be different than the previous vowel variable, which is the vowel, diphthong, or glide that comes before the target vowel token. For instance, in *teléfono* ‘telephone’, if we look at the final /o/ as the target vowel, then the tonic vowel is /e/ and the previous vowel is /o/. Another example of this is *ejercicio* ‘exercise’, where the target vowel is the final /o/, the tonic vowel is /i/ and the previous vowel is the glide /j/. However, there is frequent overlap between these categories and oftentimes the tonic vowel is the same as the previous vowel. For example, for the word *hacen* ‘they do’, the target vowel is the final /e/ and both the tonic vowel and the previous vowel are /a/. Therefore, because of the tendency for there to be overlap between these two factors, they were never included in the same analysis. Based on the ranking of the order of importance of the variables from the random forest, either tonic vowel or previous vowel was added to the initial statistical models, depending on which was ranked highest.

Surprisingly, the tonic vowel variable is only a significant predictor of raising for the DAPC for /o/. For the DAPC we see more raising when the tonic vowel is high, especially when it is the high, back vowel, /u/. This suggests that coarticulation plays a role for /o/ and the higher nature of a preceding tonic /u/ influences the articulation of the target vowel, pulling it more towards a higher space in the vocal tract. Studies on vowel raising (Navarro Tomás 1948, Holmquist 1998, 2005, and Oliver Rajan 2008) point to the tonic vowel as an important factor that influences raising. However, vowel raising in
Colongo is less subject to coarticulation with the tonic vowel than raising in other varieties of Spanish.

Previous vowel only turned out to be a significant predictor for F2 frequencies for /e/. The groups that correlate with the highest F2 frequencies for /e/ are /ej/, such as in veinte ‘twenty’ and /je, aj, i/, such as in tienen ‘they have’, baile ‘dance’, and domingo ‘Sunday’. Thus, tokens in these previous vowel groups have a more fronted articulation, which could be the result of coarticulation with a preceding high, front vowel or glide. Vowel raising studies have typically only looked at the tonic vowel as a predictor of raising (Navarro Tomás 1948, Holmquist 1998, 2005). However, Oliver Rajan (2008) included a variable called “neighboring element to the left” which captures either the tonic vowel or the glide to the left of the target vowel. Barnes (2013) included a “preceding segment” variable which included both consonants and vowels. Thus, this is the first investigation to differentiate between the tonic vowel and the previous vowel, each as its own distinct variable, in the analysis of vowel raising. Overall, neither tonic vowel nor previous vowel tend to be as important predictors of raising in this dialect as they have been in previous studies on vowel raising.

5.3.8 Number of syllables in the word

We do not have as clear of a pattern for the number of syllables factor as we have seen for other variables. The number of syllables in the word is a significant predictor of F2 frequencies for /e/. We see that words with seven syllables have the most raising overall. The seven syllable word, which is a really uncommon number of syllables in
Spanish, is *obligatoriamente* ‘obligatorily.’ There is only one occurrence of a word with seven syllables and thus it is difficult to determine whether the raising really is due to the number of syllables or whether it is an effect of the word itself. The same can be said for the six syllable word, *originalmente* ‘originally,’ where we find that the final /e/ token is non-raised. Words with two syllables have significantly higher F2 values than words with three, four, five, or six syllables. Thus, we see that the shorter words tend to have more raising. We can see the overall trends in the data in table 66, where we see for /o/ there is a slight trend towards more raising with a greater number of syllables, although these differences are not statistically significant. Most previous studies on vowel raising only consider words with two syllables (Navarro Tomás 1948, Holmquist, 1998, 2005), but Oliver Rajan (2008) found that words with three syllables, for /e/, and four syllables, for /o/, have the most raising. My results for /o/ also show the most raising in words with four syllables, but for /e/ the most raising occurs in the two syllable words, after considering the possible lexical effect of the one raised seven syllable word. Since Oliver Rajan did not have any examples of words with seven syllables in her data, and I only have one example in my data, it is difficult to make a comparison. In summary, we see a tendency for more raising in shorter words for /e/ and a slight trend towards more raising in longer words for /o/.
### Table 66: Distribution of tokens for number of syllables for DAPC

<table>
<thead>
<tr>
<th></th>
<th>/o/</th>
<th></th>
<th>/e/</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-raised</td>
<td>Raised</td>
<td>Total N</td>
<td>Non-raised</td>
</tr>
<tr>
<td>2 syllables</td>
<td>1603 (88%)</td>
<td>210 (12%)</td>
<td>1813</td>
<td>284 (21%)</td>
</tr>
<tr>
<td>3 syllables</td>
<td>661 (87%)</td>
<td>101 (13%)</td>
<td>762</td>
<td>91 (31%)</td>
</tr>
<tr>
<td>4 syllables</td>
<td>171 (85%)</td>
<td>30 (15%)</td>
<td>201</td>
<td>32 (26%)</td>
</tr>
<tr>
<td>5 syllables</td>
<td>13 (93%)</td>
<td>1 (7%)</td>
<td>14</td>
<td>5 (42%)</td>
</tr>
<tr>
<td>6 syllables</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7 syllables</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

5.3.9 Lexical category

For the lexical category factor the results are not as clear as for other factors. One pattern that does emerge is with the pronouns. For the DAPC for both /o/ and /e/ we see that pronouns are in the lexical category group with the most raising. Pronouns are in the group with the lowest F1 values for /o/ and /e/, which coincides with the raising results. However, for F2 for /e/ we see the highest frequencies in prepositions, and pronouns are in the group with the lowest F2 values, meaning that the target vowels are articulated further back in the mouth. It is a bit difficult to compare these results to Holmquist (2005) since he only had nominal, verbal, and ‘other’ categories. Oliver Rajan found that “it is not clear what differences across grammatical categories play a strong role” (2008: 154). My results are similar to Oliver Rajan in that sense as we do not see any clear differences, except for the pattern with the pronouns. This is something I will address further in the
next chapter where I discuss possibilities for future research. Now that I have discussed each of the independent that were found to be significant in the statistical analyses, I expand on the theoretical implications of vowel raising.

5.4 Theoretical implications

In this dissertation I present the hypothesis that vowel raising in Colongo is an instance of vowel weakening and can be analyzed as an example of such a vocalic process. I argue that my results support this Weakening Hypothesis, detailed in chapter 2, and here I review the evidence that substantiates this claim. I propose that vowel raising as a weakening process refers to a reduction in the number of vowel contrasts as well as a reduction in terms of duration (see chapter 2). This idea is corroborated by Flemming’s (2004) study on southern Italian dialects where he also ties a reduction in contrasts in unstressed positions to a reduction in duration. I observe more raising in contexts in which shorter duration has been found, although note that I do not look specifically at duration in this study. I consider vowel raising and unstressed vowel devoicing (UVD) together under the larger category of vowel weakening, both triggered by a reduction in duration, and consequently, I would expect certain similarities in the behavior of both processes. For example, we see that utterance final positions correlate with more raising and UVD than medial positions. The utterance final position has been considered a weak position where we find a drop in subglottal pressure, decreased articulatory effort, and/or supralaryngeal weakening (see Vayra and Fowler 1992, Fougeron and Keating 1997, Barry and Adreeva 2001, and Delforge 2008a), and this is precisely where we tend to
find more raising. By considering vowel raising as a weakening process, it is not surprising to see these results in a position where we also see more devoicing (Delforge 2008a). We also find more raising for /o/ in closed syllables which is precisely where Delforge (2008a) finds that UVD is more likely to occur, thus supporting the idea that this is a context where vowel weakening processes tends to occur, and that is why we also see vowel raising more frequently in these contexts. We should also consider the shorter duration of the vowels in closed syllables (Maddieson 1985, Almeida 1986, among others), as the contexts that lead to reduced duration correlate with more raising. Further support for the weakening hypothesis comes from the highest degree of raising found in words with penultimate stress. Words with penultimate stress have target vowels in the post-tonic position, which has been shown to be the weakest position with respect to stress location (see Arvaniti 1991, de Jong 1998, Cole et al. 1999, and Campos-Astorkiza (forthcoming)).

Thus, many of the factors that have proven to be significant for vowel raising are also factors that have been proven significant for other vowel weakening processes, especially UVD. Note that both tend to occur in contexts where there is reduced duration, even to the point of deletion in some cases for UVD, which suggests that the motivation for the two processes is similar. We also discussed in chapter 2 how Mexican Spanish is a variety that exhibits frequent vowel weakening in the form of UVD, and although the studies do not mention Michoacán specifically, I found evidence of both devoicing and elision in my data, as discussed in chapter 3. Thus it is not surprising that we see evidence for another type of weakening process in the same dialect, as examined in this
dissertation. Note that although I have focused on many similarities between vowel raising and UVD, there are some differences between the two processes. For instance, in chapter 2 I discuss studies that show that UVD can occur in pre-tonic and tonic positions, yet there is no evidence of vowel raising in the same contexts in the Michoacán dialect. We find raising only in post-tonic contexts, and these positions have been shown to be weaker than pre-tonic positions (Lipski 1990). Therefore, I propose that we consider unstressed vowel raising an instance of a separate vowel weakening process. Both Flemming (2004) and Crosswhite (2004) consider vowel raising as a form of weakening in their discussion of the reduction in contrasts in unstressed positions (see section 2.4).

We have also seen significant coarticulatory effects, especially from directly adjacent sounds, that reinforce the effects of weakening. For instance, we see a significant effect of coarticulation both from the previous consonant and the following sound. A higher and more fronted articulation of adjacent segments, such as palatals, on either side of the target vowel results in more raising. This could be explained by the raising and fronting of the tongue body for the palatal articulation, especially if we compare this to the articulation of a velar consonant, which then affects the preceding or following vowel based on the use of the same articulator. Browman and Goldstein (1992) explain that when an adjacent consonant and vowel share the same articulator, it is difficult for them both to reach their targets and this results in coarticulation due to the overlap in gestures. The authors also find that coarticulatory effects are more likely and greater when sounds are reduced (see also Scarborough 2004), which goes hand in hand with the Weakening Hypothesis.
Coarticulation seems to play more of a role in changes to the second formant than in changes to the first formant. In fact, for the F2 for /o/ we see that the previous consonant plays a significant role, even above the random effect of the individual speaker (see figure 31). Previous consonant and following sound are both significant factors for F2 for both /o/ and /e/, but previous consonant is not a significant predictor for F1 frequencies for /o/. Additionally, previous vowel plays an important role only in the F2 frequencies for /e/ and tonic vowel is not a significant factor in determining formant frequencies. This is interesting because previous vowel raising studies (Navarro Tomás 1948, Holmquist 1998, 2005) generally point to the high nature of the tonic vowel, which is typically the same as the previous vowel, as a significant predictor of raising. In the current data we would expect to see this in the form of lower F1 values. However, we see small effects of the tonic vowel and previous vowel on raising in the current study, which is further evidence that vowel raising in Colongo is clearly not a case of vowel harmony, and this also suggests that coarticulation is not as significant as it has been in other dialects. Additionally, the results for previous consonant and previous vowel discussed above could suggest that changes in F1 are due less to coarticulation than changes to F2.

Finally, in section 5.1 I mentioned that vowel raising is different for /o/ and /e/. Although the prerequisites are the same, i.e. unstressed post-tonic mid vowel, the results have shown that this vowel raising is not a monolithic process. If we were to treat the mid vowels together as a group, we would be missing out on the different patterns of behavior between the two vowels. We see significantly more raising for /e/ and in general it is constrained by fewer independent variables (see table 55). Thus, the independent factors
play a more significant role in the raising decision for /o/. For example, we see a tendency for more raising and fronting after a previous or tonic high vowel or glide for /o/ where we see the most raising when the tonic vowel is /u/, which not only is a high vowel, but a back vowel as well. Yet /e/ is not as influenced by the independent factors, i.e. it is much more likely to be raised regardless of the context. For these reasons, I propose that /e/ raising is a more phonologized process (Hyman 1975, Blevins 2004), i.e. it is in a more advanced stage. By this I mean that for /e/ raising has become more of a phonological process, where we see less phonetic variation and more of a categorical nature.

We should consider a combination of factors motivating this difference between /o/ and /e/ raising. One explanation is that because of its morphological status, /o/ carries more meaning and thus is less likely to be modified. Another possibility could be that /e/ has more room to move to a higher and more fronted position because there is more space in the front of the vocal tract than in the back. On the other hand, since /o/ has less room to move, it is less likely to be raised. In addition, we could consider the difference between a raised and non-raised /e/, i.e. [e] vs. [i], as more perceptually salient than the difference between raised and non-raised /o/, i.e. [o] vs. [u]. This possible perceptual difference could explain why we see that participants from the open network tend to have relatively high rates of /e/ raising, in contrast to the statistically lower rate of /o/ raising, when compared to the closed network. We could take the perceptual prominence of the two raised variants into account and hypothesize that the participants from the open network most uniquely identify /e/ raising with the Colongo community, and therefore
are more likely to use this feature upon their reintegration into the community, but this hypothesis would need to be corroborated with perception and attitudinal studies.

Overall, we can see that there is not one single explanation to account for the fact that we see more /e/ raising in this community, but this would be a very interesting topic for future studies (see section 6.3). We also see more raising in the Colongo community than has been documented for other varieties of Spanish with vowel raising. For instance, Oliver Rajan (2008) found /e/ raising 16% of the time and /o/ raising 21% of the time, with an overall raising rate of 18.4% in Puerto Rican Spanish. For the same dialect, Holmquist (2005) found /e/ raising 39% of the time and /o/ raising 38% of the time, with an overall raising rate of 39%. In Colongo, I found /e/ raising 77% of the time, /o/ raising 12% of the time, with an overall raising rate of 38%. Thus, the raising rate for /e/ in Colongo is much higher than in previous studies and the raising rate for /o/ is much lower. However, the overall rate of raising is similar to what Holmquist found, but higher than what Oliver Rajan found in Puerto Rico. This thorough investigation has been very fruitful to our understanding of the vowel raising process in Colongo and to advance the Weakening Hypothesis. While there are similarities with other vowel raising processes, this systematic study of Colongo vowel raising has provided insight into the unique trends in this community. In the next chapter, I present a summary of the findings of my dissertation, the contributions, and directions for future research.
Chapter 6. Conclusions

6.1 Summary of findings

The Spanish vowel system is traditionally referred to as stable, but recent research, discussed in chapter 2, presents evidence for variation in the vowel system, including unstressed vowel devoicing, vowel harmony, hiatus resolution, variation due to language contact, and unstressed vowel raising. This dissertation explores the connection between sociolinguistics and phonology by combining linguistic theory with instrumental results in the study of vocalic variation in the Spanish spoken in Colongo, Michoacán, Mexico. Working within the field of sociophonetics, I take into account both the phonological behavior, in the form of acoustic information and the results from the phonological analysis, and the social factors that play a role in variable vowel raising. My results allow me to make claims about phonological theory in addition to exploring the social status of vowel raising. I include an acoustic measurement of the first two formants of the unstressed mid vowels /e/ and /o/ and their variable realizations as [e, i] or [o, u], respectively. The data come from recordings with 31 native speakers that I collected while in Mexico. Approximately 150 unstressed mid vowel tokens per speaker, for a total of 4,586 total vowel tokens, were measured acoustically and coded for a variety of linguistic and social variables described in chapter 3. I incorporated social networks,
based mainly on mobility, into the analysis in order to account for social variables that are highly correlated.

My results show that unstressed mid vowel raising in Colongo is a distinct process from the vowel raising that has been most thoroughly studied in northwestern Spain and Puerto Rico. First of all, there is more /e/ raising than /o/, and at much higher rates than has previously been found in other regions. While some of the same independent variables are significant, the direction of raising often differs from previous studies. The results show a tendency for more raising with tonic vowels or previous vowels that are high or glides as well as significantly more raising with previous consonants that are palatals, which supports the results from previous research on vowel raising in other Spanish varieties. The results also show that gender and social network are significant independent variables. The gender differences may be based on anatomical differences, but membership in the closed social network correlates with higher levels of raising and a more fronted articulation of /e/. Thus, even though this is a small, homogenous community, there are differences based on social factors. Based on this evidence and anecdotal evidence from my participants, I propose that vowel raising indicates membership in the local community, is part of the Colongo identity, and is heavily influenced by mobility. Overall, I have provided evidence for vowel raising as a weakening process based on similar behavior to other weakening processes, such as unstressed vowel devoicing which supports the idea of a Weakening Hypothesis (see section 5.4). Additionally, the results support the proposal that /e/ raising is a more phonologized process that is more frequent, more categorical, and less context dependent.
6.2 Contributions

My research contributes to dialectological, phonological, phonetic and variationist literature about Mexican Spanish. As far as vowel raising, I provide the first systematic description of this process in rural Michoacán by including an acoustic analysis of each vowel token. Thus, this dissertation adds to the vowel raising literature by going beyond the more typically used impressionistic analysis and including acoustic data. Moreover, by utilizing acoustic measurements I use a more objective method to provide a more reliable description of the vowel raising process and this also facilitates the replication of this type of study in the future. The methodological approach used in this study is different than what others have done in vowel raising studies in other varieties of Spanish not just in terms of the use of formant values, but also in the factors that were considered. I found vowel raising in non-final position, which has been mentioned, but not thoroughly analyzed before. Type of syllable and following sound were also included in the analysis, and they both are significant predictors of raising and changes to formant values as indicated in chapter 4. The study of these particular variables is relatively new to the study of vowel raising having only been proposed by Oliver Rajan (2008) and Barnes (2013), respectively. I provide evidence for a distinct type of vowel raising in Colongo, where /e/ is much more commonly raised than /o/, and at a much higher rate than in previous studies.

Apart from vowel raising, this study also contributes to our overall knowledge of Michoacán Spanish. Social networks are used to elucidate the social differences among
the members of a small, seemingly homogenous community. This study gives a detailed explanation of exactly how the social networks were created which could be useful for future studies in small, rural towns. Furthermore, social networks are shown to be a useful sociolinguistic tool that can work around social factors that are highly correlated. My dissertation also explores the phonetics and phonology interface. I use acoustic data to make contributions to phonological theory more precisely by expanding our understanding of the Weakening Hypothesis. I add to theories of vowel weakening by using the acoustic measurements of the target vowels to show that vowel raising and unstressed vowel devoicing tend to occur in the same contexts.

6.3 Directions for future research

This dissertation is an important first step in the investigation of the vowel raising phenomenon in rural Michoacán. Taking the conclusions reached here as a point of departure, there are several issues that would benefit from future research. In order to obtain a more general picture of the behavior of post-tonic vowels in general, future studies should analyze not only mid vowels but all vowels, paying special attention to the low vowel /a/. By measuring the formant values for /a/, we will be able to tell if the low vowel is also being raised, which would be evidence to support the idea that the vowel raising found in Michoacán is similar to what Flemming (2004) finds in Italian dialects (see section 2.4). This would allow us to further expand Flemming’s account of vowel weakening within Dispersion Theory to vowel raising in Colongo. If there is no change in /a/, this would suggest that the vowel raising in this dialect is more similar to what is
found in the Luiseño dialect by Crosswhite (2004) (see section 2.4). By measuring the formant values of all the vowels in post-tonic position, we can provide a more detailed description of the whole vocalic system and we can investigate the differences between raised vowels and underlying high vowels. With this data we could confirm our prediction (discussed in section 5.1) that the raised /o/ has higher F2 values that differentiate it from the underlying /u/. To further test our Weakening Hypothesis, it would be interesting to measure the duration of the target vowels in order to determine whether durational differences exist between raised and non-raised vowels. Based on our conclusions, the prediction is that raised vowels would be shorter than non-raised ones, correlating with a reduced duration for the environment where raising takes place.

Finally, lexical frequency should also be considered since this factor has been shown to be correlated with reduction (Bybee 2001) and consequently, we would expect an effect, especially for /o/, which is more prone to be influenced by internal factors. Furthermore, exploring the effects of lexical frequency and priming could help elucidate differences between different lexical categories and also in words with different numbers of syllables.

We have seen that unstressed vowel devoicing (UVD) is prevalent in Mexican Spanish, as explained in section 2.3.1.1, and this process may interact with vowel raising since both target similar vowel locations. It would be extremely beneficial to provide a sociophonetic description of UVD in rural Michoacán Spanish, focusing on the relationship between this process and vowel raising. Such a study would help to further advance our Weakening Hypothesis and provide direct evidence for the similar behavior
of UVD and raising in this dialect of Spanish. Additionally, the UVD process should be explored in order to determine how UVD in Colongo is similar or different to other regions in Mexico and/or the Andean region.

Finally, another research direction that stems directly from the conclusions reached in this dissertation is to explore the impact of migration to the United States on the speech of Mexican speakers. More precisely, the variable vowel raising of members of the Colongo community who now live in the United States should be investigated, in order to compare the rates of vowel raising to those who remain in Colongo, and note differences due to language and dialect contact with English and other varieties of Spanish. I would anticipate lower vowel raising rates when these former Colongo community members are in a more linguistically diverse living situation where they are exposed to other varieties of Spanish, and higher rates when they are in a more isolated location where they mainly interact with speakers from their same region in Michoacán.

As an extension of my current project, it would be interesting to re-interview several of my original participants who have now left Colongo for a short time (to visit the United States) to determine if there are changes to their vowel raising based on language and dialect contact. In order to complement the data from the current study, it would also be helpful to go back to Colongo to conduct a study on attitudes and social perceptions about vowel raising. Using a perception study would help to provide a better description of the social role of vowel raising and how that is related to identity. In addition, this would give us a more thorough understanding of the importance of mobility and how it is related to social meaning. An additional complement to the current study
would be to add more participants that have spent time outside of the community. In this manner, we could gain more insight into the role of social networks using a population that is more equally distributed in terms of mobility.
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