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review

¿Lo hacis o no lo haces? Mid vowel raising as a form of vocalic weakening

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Abstract

The current study analyzes vocalic variation in the form of unstressed mid vowel raising in the Spanish of rural Michoacán, Mexico. In this variety of Spanish, the post-tonic unstressed mid vowels /e/ and /o/ are variably produced as their high counterparts [i] and [u]. Unlike other dialects with vowel raising (for Puerto Rico see Navarro Tomás 1948; Holmquist 1998, 2005; Oliver Rajan 2007, 2008), there is significantly more raising of /e/ than /o/. After determining the linguistic factors that favor vowel raising, namely the vowel appearing in closed syllables and utterance-finally, a weakening hypothesis is proposed. Unstressed mid vowel raising tends to occur in many of the same contexts where unstressed vowel devoicing (UVD) has been shown to occur (Delforge 2008a, 2008b), although there is typically no change in vowel quality with UVD, and both are triggered by a reduction in duration. Therefore, I provide support for the idea that unstressed mid vowel raising should be classified as its own separate vowel weakening process.

1. Introduction

Vowels in Spanish are normally considered stable across dialects, typically in contrast with the amount of widely-documented variation in consonants (Hualde 2005). However, there is increasing evidence of dialectal differences in vowel production, such as studies on vowel raising and vowel devoicing (several are presented in Campos-Astorkiza 2014), which supports further research into vocalic variation. The present study analyzes vocalic variation in the form of unstressed mid vowel raising in the Spanish of rural Michoacán, Mexico. In this variety of Spanish, the post-tonic unstressed mid vowels /e/ and /o/ are variably produced as their high counterparts [i] and [u]. This investigation determines the linguistic factors that contribute to variable raising of mid vowels. At the same time, it is important to point out that Mexican Spanish in general is characterized as having unstressed vowel devoicing (UVD), which typically refers to a reduction in duration, devoicing, or perceptual deletion of the vowel. Therefore, the factors that have been shown to contribute to UVD must also be considered and compared with the analysis of post-tonic unstressed mid vowel raising.

It is first necessary to discuss previous research regarding unstressed vowel raising and UVD in addition to theories of vocalic weakening. The subsequent section will detail the current study, with information about the community and participants, collection of the data, and the variables included. The results and discussion sections follow, where I present the idea for a weakening hypothesis, before presenting the conclusions and areas for future research.

2. Previous research

While many researchers discuss how vowels in Spanish are produced in a similar manner, even across dialects (see the acoustic analyses of Quilis and Esgueva 1983; Martínez Celdrán and Fernández Planas 2007; Morrison and Escudero 2007), there is an increasing amount of research demonstrating variation in the Spanish vocalic system. In some instances, this variation can be attributed to language contact situations. For example, interactions with Kichwa in Ecuador (Guion 2003), Quechua in Peru (O'Rourke 2010), Austurian in Spain (Barnes 2013), and English in the Southwest of the United States (Willis 2005) and the Chicago area (Ronquest 2013) have resulted in changes to the vocalic systems of Spanish speakers (and heritage speakers in the case of Ronquest 2013). However, this article will focus more on varieties that do not have significant contact with other languages, since this presents a more comparable situation to that of the Michoacán speakers in this study.

2.1 Unstressed vowel raising

Vowel raising, typically of an unstressed mid vowel to a high vowel, has been mentioned in the literature about the Spanish of Colombia (Flórez 1951), Puerto Rico (Navarro Tomás 1948; Holmquist 1998, 2005; Oliver Rajan 2007, 2008), Mexico (Boyd-Bowman 1960; Cárdenas 1967; Lope Blanch 1979; Moreno de Alba 1994; Parodi and Santa Ana 1997; Parodi 2001), and the Dominican Republic (Bullock et al forthcoming, 2010). Unfortunately, since the vowel raising itself is not the main focus of all of the studies listed (this is especially the case for Mexico), there is at times just a note that vowel raising has been heard or tends to occur in a particular region. In what follows, I will discuss the research on vowel raising that has been most influential for the present study.

Navarro Tomás (1948) was one of the first to study mid vowel raising in the western region of Puerto Rico. By listening to spoken speech of his informants, he determined that raising was most likely in word-final position, especially when preceded by a high vowel, a diphthong, or a palatal consonant. Building on these findings, Holmquist (1998, 2005) examined mid vowel raising in the speech of 60 participants in the rural, agricultural community of Castañer. His findings are similar to Navarro Tomás' (1948) in that Holmquist also found more raising after a high tonic vowel or a preceding palatal. Additionally, Holmquist found that back vowel raising was more frequent than front vowel raising, and that there was more raising in words from what he named the 'nominal' and 'verbal' morphological categories[1] as opposed to the 'other' category that included tokens such as *donde*, *como*, and *últimamente*.

Oliver Rajan (2007, 2008) added to the growing research on vowel raising in Puerto Rico with an auditory impressionistic study, coupled with an acoustic analysis of some of the vowels for verification of the auditory impressions. In her analysis of 6900 tokens (100 each from 69 interviews), there was significantly more back vowel raising than front vowel raising and both front and back vowels were more likely to be raised after a high vowel or glide. Oliver Rajan's (2008) work has been especially helpful to the current research since she also introduced a number of variables that had not been previously considered in vowel raising studies. Among her many important findings was the discovery of more raising in words with antepenultimate stress when compared to penultimate stress, and in words with no onset or a deleted onset when compared

1 Holmquist (1998) does not specify the types of words included in the 'nominal' and 'verbal' morphological categories, but does provide examples from the 'other' category (which I have listed above).

to other types of onsets. Finally, Oliver Rajan indicated that vowel raising can occur in non-final position and in closed syllables. These studies on vowel raising in Puerto Rico have influenced the decisions on which variables to include and how to analyze the vowels themselves in this study.

As mentioned above, there are not as many studies that focus specifically on mid vowel raising in Mexico. Lope Blanch (1979) discusses final mid vowel closure in Michoacán. His informants came from various cities within the state, including Morelia, Zacapu, Gurachita, and Zamora, the last city being in close proximity to the area where the data was collected for this study. Using what appears to be an auditory determination of raising based on the pronunciation of a list of prepared words, Lope Blanch aimed to find the contexts that favor raising. He found that raising was more likely after a palatal consonant and also with the back vowel after a velar consonant, which both suggest 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. Lope Blanch adds that raising is common before a pause, which happens to be the same position where devoicing commonly occurs with vowels and even some consonants, to be discussed in the following section. Moreno de Alba (1994) presented data about vowel raising in the *Atlas lingüístico de México* (ALM) 'Linguistic Atlas of Mexico'. He found raising in several states, including Michoacán, and his findings suggest /o/ raising occurs more frequently than /e/ raising. The current study will contribute to this literature on unstressed mid vowel raising in Mexico by examining additional factors that favor raising.

2.2 Unstressed vowel devoicing

Unstressed vowel devoicing[2] (UVD) refers to a range of changes to unstressed vowels, from reduction of duration and devoicing to complete loss of the vowel. Note that typically the vowel quality is not changed in this process, so UVD is a different phenomenon from the topic of this investigation, unstressed mid vowel raising. UVD is typically associated with both Mexican and Andean Spanish. Since this distinct process is prevalent in Mexican Spanish, the results from previous studies will be considered in the analysis of my own data, alongside unstressed mid vowel raising.

Researchers have examined the range of changes to unstressed vowels in Mexican Spanish (Boyd-Bowman 1952; Canellada de Zamora and Zamora Vicente 1960; Lope Blanch 1963; Perissinotto 1975, among others), and several point out that this salient feature is quite noticeable to speakers of other dialects. The most common finding has been that UVD tends to occur most frequently when the vowel is in contact with voiceless consonants, especially /s/. Since UVD was often found in closed and final syllables, these findings will need to be considered in the present study because these are positions where vowel raising tends to occur as well. Since the contexts in which the range of changes to unstressed vowels occurs are similar, perhaps these two distinct processes could be considered as different types of vowel weakening.

2 UVD is the terminology used by DelForge (explained in the following paragraphs). Other authors have typically referred to this process as unstressed vowel reduction, UVR. For clarity and consistency I will use the acronym UVD throughout.

Unstressed vowel devoicing has also been studied more recently (than the studies mentioned above) in several varieties of Andean Spanish, including those of Ecuador (Lipski 1990), Bolivia (Gordon 1980; Sessarego 2012a, 2012b), and Peru (Hundley 1983; Delforge 2008a, 2008b). Lipski (1990) finds that UVD in Ecuadorian Spanish usually occurs with the front vowels /e, i/ in contact with /s/. He concludes that UVD occurs in the weakest prosodic segments (signifying that UVD is more prevalent in post-tonic word-final syllables than in pre-tonic syllables), and also finds that UVD tends to occur more frequently in closed syllables, typically next to a voiceless consonant, than in open syllables.

Delforge (2008a, 2008b) uses acoustic analysis and the framework of Articulatory Phonology (Browman and Goldstein 1989, 1992) to show and explain the gradient effects and variable occurrence of UVD in the Spanish of Cuzco, Peru. Her initial spectrographic analysis showed that 9.9% of unstressed vowels were reduced or devoiced. She also 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, and found that centralization is not occurring[3]. Therefore, Delforge opts to describe it as unstressed vowel devoicing (UVD) instead of the more 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 article. 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. The presence of other voiceless consonants either before or after the vowel can trigger the same amount of devoicing as /s/. Moreover, the author found that 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%).

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 the ones that are most frequently reduced in duration, elided, or devoiced, and those are the very same vowels analyzed in this 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. 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[4].

2.3 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. I argue that vowel raising can be seen as another type of vowel weakening process based on the variable reduction in contrasts, when /e/ and /o/ are raised to [i] and [u], combined with the reduction in duration that result from this raising phenomenon. In order to explain the results presented here within a vowel weakening framework, it is important to first review previous analyses that have been proposed to account for vowel weakening. I focus on vowel weakening theories with a special emphasis on raising

3 It should be noted that centralization has been a documented feature in several studies on weakening (see Lipski 1990, among others).

4 See Barajas (2015) for an initial analysis of devoiced tokens in this data set.

in unstressed positions (see Lindblom 1963; de Graaf 1987; Duke 1993; Steriade 1995, 1997; and Crosswhite 2001 for further work on vowel weakening).

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. I focus on how Flemming applies his Dispersion Theory to vowel contrasts, more specifically to the cases where the number of vocalic contrasts decreases in unstressed syllables due to vowel raising. He illustrates this 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). According to Flemming, this pattern manifests because, in unstressed positions, it is harder to make the distinctions in F1 contrasts. He 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 lower 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 as well, suggesting a cross-linguistic trend. 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. Overall, Flemming (2004: 245) 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[5], 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], resulting in 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. An-

5 Crosswhite (2004) refers to these processes as reduction, but I have chosen to use the term weakening as a synonym for what she calls reduction.

other example of weakening via raising (Crosswhite 2004:199) has been attested to in the Native American language Luiseño, where the mid vowels are raised to high vowels, resulting in only the three corner vowels in unstressed positions. Using Optimality Theory, Crosswhite proposes a licensing constraint which captures the difficulty of perceiving the contrasts between vowels in unstressed positions. 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/. This is interesting to consider for the present study since the vowel raising pattern appears to be similar in the Colongo dialect in Michoacán, Mexico.

3. Current Study

The data for the current study were collected in a small town of approximately 700 inhabitants[6] called El Colongo, affectionately known as *un ranchito* 'a little ranch'. Colongo is located in the northwest region of the state of Michoacán, within the municipality of Ixtlán de los Hervores, with the closest big city being Zamora. Colongo is a small, rural community whose economy is mainly based on agriculture, which is similar to the communities in Spain and Puerto Rico where vowel raising has been more extensively studied. Although many members of the community work in the fields or sell goods or food from their own home, most are dependent on money sent from family members in the United States. Interestingly, there is no noticeable presence of indigenous languages in the community, except possibly when visitors attend their yearly town festival.

Sociolinguistic interviews were recorded with 31 participants who were recruited using the "friend of a friend" method. All one-on-one interviews were conducted in a private residence. The participants are 16 females and 15 males within the age range of 13-84 (median age 31, mean 37). The education level ranges from no school to completion of secondary school, with the majority of the participants having completed at least a few years of primary school. Most of the participants have never left the community. The participants talked about a variety of topics in the interviews, including personal life, work, and local celebrations, which resulted in a series of 31 interviews ranging in length from 15 minutes to 1 hour long, with the average interview lasting approximately 30 minutes.

3.1 Data Analysis

After an initial auditory analysis, it was determined that vowel raising virtually never occurs in pre-tonic syllables or mono-syllabic words in this community. Therefore, only post-tonic unstressed mid vowels from multi-syllabic words were included for further auditory and acoustic analysis. Exclusions from the analysis included target vowels followed by another vowel due to possible interactions between vowels, such as diphthongization or fusion. For example, the target vowel /e/ in *bail<u>e</u> y* 'dance and' was excluded from the analysis since it is followed by /i/.

6 Information obtained from http://en.mexico.pueblosamerica.com/i/el-colongo/ on 6-22-17.

Additionally, any vowels that were devoiced or reduced in duration to the point that no formant values could be measured, e.g., cases of unstressed vowel devoicing (UVD, see Delforge 2008a), were excluded. After using these guidelines to determine which target vowels were included, approximately 150 mid vowel tokens were coded per speaker[7], for a total of 4,586 analyzed vowels in the analysis. Based on the results from prior research on other dialects of Spanish (see Holmquist 1998, Oliver Rajan 2008) and differences in acoustic measurements, /o/ and /e/ were considered as separate dependent variables.

There was an auditory and acoustic analysis for the unstressed post-tonic mid vowels. For the auditory judgment, I made a raised or non-raised determination, following the methodology of many of the previous vowel raising studies. As for the acoustic analysis, I measured the first and second formants in the middle of the target vowels (F1 and F2) using the software program Praat (Boersma and Weenink 2013) to obtain the measurements. I manually marked the beginning and end of each vowel and took the formant measurements from what Praat deemed to be the middle point. 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 converting them to the ERB scale, which is an auditory scale using bark as the measurement (Traunmuller 1997). I then used the normalized ERB values for F1 and F2 of each token to create two continuous variables which were then used as the input for the analysis described next[8].

Instead of relying solely on auditory judgments, as had been frequent in previous studies on vowel raising, I opted instead to rely on the Discriminant Analysis of Principal Components (DAPC; Jombart 2008, Jombart, Devillard and Balloux 2010) to make the categorical distinction between raised and non-raised vowels. Recent work on vowel raising in Asturias, Spain by Barnes (2013) has demonstrated the benefits of using the DAPC and was the first to apply DAPC to the analysis of vowel raising. This method has also proven to be successful in perception studies aimed at determining the role of formant frequencies in distinguishing between male and female voices in English (Hillenbrand and Clark 2009). 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' methodology). The DAPC determines the statistical probability of belonging to one of the two groups for each vowel token. In the data for this study, there were many cases of category overlap in the auditory judgments, meaning that two tokens that had similar F1 and F2 values had 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, based on the formant values, between the raised and non-raised categories.

Barnes (2013) discusses several reasons why 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

7 For several speakers I was unable to reach 150 tokens due to the duration and/or quality of the recording. However, there was only a difference of approximately 10-12 tokens less for these speakers.

8 Note that for the present study only the results based on the DAPC determination are used and the results from the continuous variables (F1 and F2) are discussed as part of a larger project (Barajas 2014).

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.

3.1.1 Independent Factors

The current analysis focuses on the independent linguistic variables that were determined to be significant in the statistical analyses[9]. Using factors that were found to be influential on vowel raising in previous research, I coded for the following variables: word location within the utterance, type of syllable, tonic vowel quality, previous consonant, following sound, stress pattern, and lexical category. Below I include a brief explanation of each of these variables (when necessary) as well as support from previous research when applicable.

Word Location within the Utterance

The first linguistic factor that 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, of which the latter was typically determined by a falling pitch pattern, a pattern found in Mexican Spanish (de-la-Mota, et al 2010).

Type of Syllable

Many of the previous studies show examples of vowel raising in words that have an open syllable, but do not specifically look at the difference in open versus closed syllables. Oliver Rajan (2008), however, provides evidence of vowel raising in both closed and open syllables. Considering the effect of vowel raising on open vs. closed syllables also allows the comparison of vowel raising to other types of vowel weakening, such as UVD.

Tonic Vowel Quality

Previous research has shown that a previous tonic syllable with a high vowel (/i/ or /u/) or high glide (/je/) triggers more raising than other tonic vowels in two-syllable words (Navarro Tomás 1948, Holmquist 1998, Oliver Rajan 2008, among others). Thus, the previous tonic vowel or glide was identified and categorized since it is expected that they have an effect on raising in this variety of Spanish as well.

Previous Consonant

Both Navarro Tomás (1948) and Holmquist (1998, 2005) found that a preceding palatal is the environment that most favors the raising of unstressed mid vowels. Oliver Rajan (2008) exam-

9 This publication is part of a larger socio-phonetic study. To see additional linguistic and sociolinguistic variables that were examined, see Barajas (2014 and 2016).

ined the onset, or lack thereof, and found that in syllables with an elided onset preceding an unstressed mid vowel, that vowel is more likely to be raised. Therefore, the previous consonants were grouped based on the point of articulation (palatal, dental, alveolar, etc.), deleted (for example *comido* where the /d/ is not pronounced, or none (for example, *novio* has no consonant before the last /o/).

Following Sound

As mentioned earlier, previous vowel raising studies have considered the influence of the previous consonant, but the point of articulation of the following sound is not as thoroughly investigated. However, Barnes (2013) found the following sound to be a significant predictor of raising in the Spanish of Spain in contact with Asturian. Additionally, 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 it is hypothesized that unstressed mid vowel raising and UVD are both instances of vocalic weakening, I examine whether the following sound affects vowel raising as well. As with the previous consonant factor, the following sound was grouped by point of articulation.

Stress Pattern

I coded for the stress pattern, distinguishing between penultimate and antepenultimate stress, since Oliver Rajan (2008) found that most vowel raising occurred in words with antepenultimate stress, such as *último* 'last'. Tokens with stress on the final syllable were excluded, since only instances of mid vowels after tonic syllables are part of the study.

Lexical Category

Holmquist (1998) and Oliver Rajan (2008) both found an effect of lexical category on vowel raising. In Holmquist's study, unstressed mid vowels in nouns and verbs were most likely to be raised. 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 multi-syllabic 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.

Summary of the Independent Linguistic Variables

I have summarized the independent linguistic variables, including the different levels for each, in table 1.

Variables	Levels	Selected examples	Translation of examples
Type of syllable	open	*vin**o***	'wine' or 'she/he came'
	closed	*ell**o**s*	'they'

Tonic vowel	/a/, /e/, /i/, /o/, /u/, /aj/, /aw/, /ej/, /ja/, /je/, /jo/, /wa/, /we/, /wi/	*vien**e**s*: /je/	'you come'
		*íbam**o**s*: /i/	'we were going'
		*grand**e***: /a/	'big'
Previous consonant	previous consonant sound	*bail**e***: /l/	'dance'
		*abaj**o***: /x/	'below'
	none	*fe**o***	'ugly'
		*novi**o***	'boyfriend'
	deleted	*sa(b)**e**s*: /b/ is deleted	'you know'
		*baila(d)**o***: /d/ is deleted	'(has) danced'
Following sound	following consonant sound	*gent**e** también: /t/*	'people too'
		*tamal**e**s: /s/*	'tamales'
	none	"*com**o***…[pause]"	'like'
Stress pattern	antepenultimate	*sábad**o***	'Saturday'
	penultimate	*quinc**e***	'fifteen'
Lexical category	adjective	*grand**e***	'big'
	adverb	*cuand**o***	'when'
	clitic	*mantenerl**o**s*	'maintain them'
	conjunction	*per**o***	'but'
	determiner	*es**e** mismo*	'that same (one)'
	interjection	*est**e***	'ummm'
	noun	*sillon**e**s*	'armchairs'
	preposition	*desd**e***	'since'
	pronoun	*un**o***	'one/someone'
	verb	*trajer**o**n*	'they brought'
Word location within utterance	within utterance	*"...cuand**o** vienen mis hijos..."*	'when my children come'
	utterance-final	*"Comen puro pescad**o**."*	'They eat only fish'

Table 1: Summary of independent linguistic variables (with levels), adapted from Barajas (2014)

4. Results

This section discusses the results from the categorical analyses. Section 4.1 begins with an explanation of the overall descriptive results, separately for /o/ and /e/, and section 4.2 follows up with the presentation of the statistical models.

4.1 Descriptive Statistical Results

4.1.1 Descriptive Results for /o/

Figures 1 and 2 show a cross between the first two formant values and the two types of categorical analysis, auditory and DAPC, for /o/. In each of these figures, 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 figure 1 and the DAPC in figure 2. Table 2 shows the distribution of raised and non-raised /o/ tokens as determined by the DAPC. In both the figures and the table we see more non-raised than raised tokens. In both the auditory judgments and the

DAPC for /o/, we see that the F1 value plays the most important role in determining the raised or non-raised distinction. We see a tendency for lower F1 values in the raised tokens of /o/ and the trend of higher F1 values for non-raised tokens.

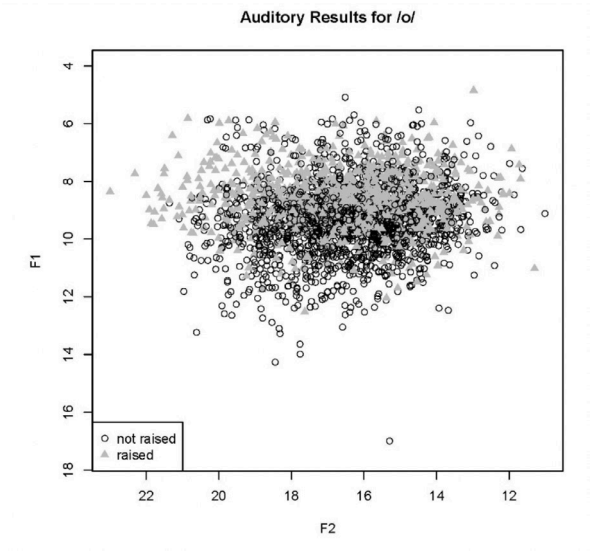

Figure 1: Auditory distribution of /o/ in the vowel space

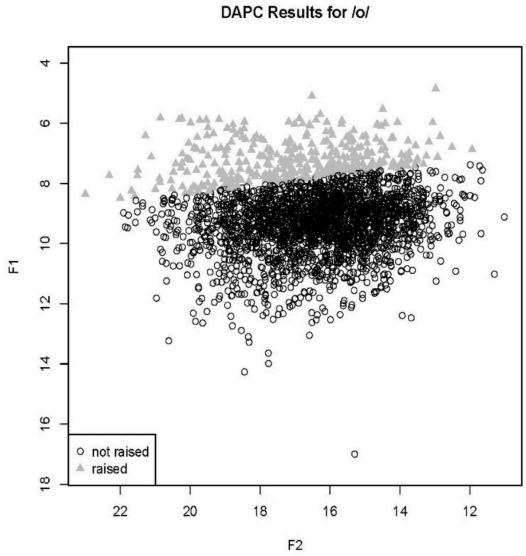

Figure 2: DAPC distribution of /o/ in the vowel space

Vowel	**Non-raised**	**Raised**	**Total N**
/o/	2447 (88%)	344 (12%)	2791

Table 2: Distribution of raised and non-raised /o/ tokens as determined by the DAPC

Table 3 shows how /o/ tokens are distributed when coded for word location within the utter-

ance. There is more raising of /o/ in utterance-final position than within the utterance. Table 4 displays the distribution of tokens by stress pattern where we see slightly more raising of tokens in the penultimate position.

	Non-raised	Raised	Total N
Utterance-final	449 (79%)	121 (21%)	570
Within the utterance	1998 (90%)	223 (10%)	2221

Table 3: Distribution of /o/ tokens for word location within the utterance

	Non-raised	Raised	Total N
Antepenultimate	100 (90%)	15 (10%)	115
Penultimate	2347 (88%)	329 (12%)	2676

Table 4: Distribution of /o/ tokens by stress pattern

4.1.2 Descriptive Results for /e/

Figures 3 and 4 show the same cross between the first two formant values and the two types of categorical analysis, auditory and DAPC, this time for /e/. Again, in each of these figures, 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 figure 3 and the DAPC in figure 4. The similarities between the auditory judgments and the DAPC analysis can be seen for /e/, in figures 3 and 4, where we see that both F1 and F2 play a role in 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 1-4. There are many cases of category overlap in the auditory judgments, where two tokens with 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. However, the DAPC creates a clear division between the raised and non-raised categories and for this reason was chosen for further analyses rather than the auditory judgments.

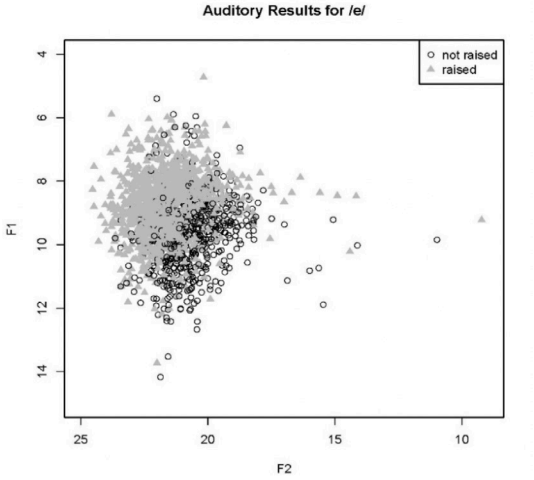

Figure 3: Auditory distribution of /e/ in the vowel space

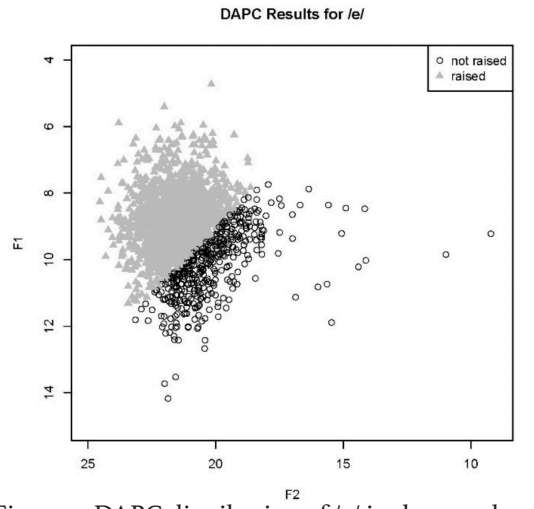

Figure 4: DAPC distribution of /e/ in the vowel space

Vowel	**Non-raised**	**Raised**	**Total N**
/e/	412 (23%)	1383 (77%)	1795

Table 5: Distribution of raised and non-raised /e/ tokens as determined by the DAPC

Table 5 shows the raw numbers and percentage of occurrence in the raised and non-raised categories of /e/ tokens as determined by the DAPC. For /e/ we see considerably more raised than non-raised tokens. The distribution of /e/ tokens by word location within the utterance is shown in table 6. For /e/ there is slightly more raising in utterance-final position when compared to tokens within the utterance. Table 7 displays the distribution of /e/ tokens by stress pattern where there is more raising of tokens in the penultimate position than in the antepenultimate position.

	Non-raised	Raised	Total N
Utterance-final	69 (20%)	270 (80%)	339
Within the utterance	343 (24%)	1113 (76%)	1456

Table 6: Distribution of /e/ tokens for word location within the utterance

	Non-raised	Raised	Total N
Antepenultimate	31 (42%)	42 (58%)	73
Penultimate	381 (22%)	1341 (78%)	1722

Table 7: Distribution of /e/ tokens by stress pattern

4.2 Statistical Models

In order to test the effect of the linguistic variables on the dependent variables, logistic and linear regression models in R were used (R Development Core Team 2011). Mixed effects models were developed 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. 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). Table 8 shows the statistically significant factors that contribute to /o/ raising, including the levels within each factor. The significant factors for /o/ raising are word location within the utterance, previous consonant, type of syllable, lexical category, and tonic vowel group.

	Estimate	*SE*	*z*-value	*p*-value
(Intercept)	0.63	0.46	1.38	0.17
Word location within the utterance (reference level is 'utterance-final')				
Within the utterance	**-1.16**	**0.15**	**-7.88**	**<0.001**
Previous consonant (reference level is 'PC group 1-no prev C')				
PC group 2 - palatal	-0.34	0.35	-0.95	0.34
PC group 3 - bilabial, labio-dental	-0.37	0.33	-1.10	0.27
PC group 4 - dental, alveolar	**-0.90**	**0.32**	**-2.84**	**<0.01**
PC group 5 - C cluster end w/ alv, vel	**-1.55**	**0.35**	**-4.44**	**<0.001**
PC group 6 - deleted	-13.91	647.22	-0.02	0.98
Type of syllable (reference level is 'closed')				
Open	**-0.56**	**0.15**	**-3.83**	**<0.001**

Lexical category (reference level is 'LC group 1-pronouns')				
LC group 2 - adj, nouns, verbs	-0.22	0.21	-1.05	0.29
LC group 3 - prep, adverb, det, clitic	**-0.58**	**0.29**	**-2.02**	**0.04**
LC group 4 - conjunctions	**-1.01**	**0.46**	**-2.19**	**0.03**
LC group 5 - poss. pronoun, interjection	-13.49	918.12	0.02	0.99
Tonic vowel group (reference level is 'TV group 1 - /u, aj, ja/')				
TV group 2 - /wi, i, a, je, e, o/	**-0.56**	**0.21**	**-2.70**	**<0.01**
TV group 3 - /wa, we/	**-1.05**	**0.38**	**-2.79**	**<0.01**
TV group 4 - /jo, iw, ej/	-13.84	975.46	-0.01	0.99

Table 8: Factors that contribute to /o/ raising

Table 9 displays the statistically significant factors that influence /e/ raising. Following sound, lexical category, previous consonant, and stress pattern are the variables that are significant for /e/ raising.

	Estimate	*SE*	*z*-value	*p*-value
(Intercept)	1.50	0.66	2.28	0.02
Following sound (reference level is 'FS group 1 - palatal, velar, bilabial, no FS')				
FS group 2 - dental, alveolar	**-0.61**	**0.13**	**-4.77**	**<0.001**
FS group 3 - labio-dental	-0.30	0.89	-0.34	0.74
Lexical category (reference level is 'LC group 1 - all others')				
LC group 2 - conjunctions	-1.93	1.21	-1.60	0.11
LC group 3 - prepositions	**-1.91**	**0.39**	**-4.90**	**<0.001**
Previous consonant (reference level is 'PC group 1 - palatal')				
PC group 2 - dental, alveolar, velar	-0.62	0.58	-1.06	0.29
PC group 3 - bilabial, labio-dental	-1.04	0.61	-1.70	0.09
PC group 4 - C cluster end w/ alv.	**-1.71**	**0.62**	**-2.77**	**0.01**
PC group 5 - no PC	-1.59	1.39	-1.15	0.25
PC group 6 - deleted	-14.80	73.90	-0.20	0.84
Stress pattern (reference level is 'antepenultimate')				
Penultimate	**1.06**	**0.27**	**3.90**	**<0.001**

Table 9: Factors that contribute to /e/ raising

Based on the results presented in this section, we can see that there are different factors that have been determined to be statistically significant to the raising of /o/ and /e/. It is clear that there are more total tokens of /o/ than /e/, and /e/ is raised more than /o/. However, despite these differences, there are also similar patterns between the two vowels. A detailed discussion of these similarities and differences, as well as their relevance to previous studies, continues in the following section.

5. Discussion

When we look at the initial auditory analysis, we can see that there are many cases of category overlap, that is, two tokens with similar F1 and F2 values have been categorized distinctly. This suggests that perhaps there are other cues present that lead to the perception differences in the sounds under study and is an opportunity for future research. Overall, the results from the previous section show that /o/ and /e/ tokens behave quite differently, with more raising of /e/ than of /o/. This is the opposite of what studies have shown in Puerto Rico and Spain, i.e., much more /o/ raising (Navarro Tomás 1948, Holmquist 1998, 2005, Oliver Rajan 2008). Additionally, as we can see by looking back to table 8 and table 9, /o/ raising is conditioned by more independent variables than /e/ raising, which I believe suggests that /e/ raising is in a more advanced phonological stage (see Hyman 1975 and Blevins 2004).

In utterance-final position, /o/ tokens are significantly more likely to be raised. For /e/ tokens, although the factor is not significant, we see a similar trend when looking at the percentages of raised tokens in utterance-final position. This can be seen in tables 3 and 6. Several studies (Steriade 1995, 1997; Shadle 1997; Meyers and Hansen 2007) discuss how common devoicing and neutralization are in utterance-final position and, as previously mentioned, Mexican Spanish is a variety that is known for devoicing. Since devoicing and vowel raising both tend to occur in the utterance-final position, this lends support to the idea of unstressed vowel raising as a weakening process.

Tokens of /o/ in closed syllables are significantly more likely to be raised, which supports cross-linguistic research on reduced vowel duration in closed syllables (Maddieson 1985). I argue that this is additional support for a viewing unstressed vowel raising as a weakening process since raising tends to occur in a context where reduction is present. Since /e/ raising is not affected by syllable type, this is further evidence that /e/ raising is less conditioned by independent factors.

The tonic vowel variable is only a significant predictor of raising for /o/, which coincides with previous studies on vowel raising (Navarro Tomás 1948; Holmquist 1998, 2005; and Oliver Rajan 2008) that point out the importance of the tonic vowel. Once again, though, we see that /e/ raising is not influenced by this variable, suggesting that there is less coarticulation with the tonic vowel in this variety of Spanish, especially considering that there is more /e/ raising than /o/ raising overall. The results for both /o/ and /e/ coincide with previous research (Navarro Tomás 1948; Holmquist 1998, 2005) and show significantly more raising of both when preceded by a palatal consonant.

As for the following sound, there is significantly more raising of /e/ when followed by the group containing palatals, and this is not unexpected given the results for previous consonant, but there is no significant effect on /o/ raising.

Stress pattern is a significant predictor of raising for /e/, with more raising in words with penultimate stress than with antepenultimate stress, and with /o/ we see a similar, though not significant, trend (see tables 4 and 7). Several studies have identified the post-tonic position as an articulatorily weak position, having the highest amount of reduction or weakening (see Arvaniti 1991; de Jong 1998; Cole et al. 1999; and Campos-Astorkiza 2015). More raising in this weak post-tonic position supports the idea of unstressed vowel raising as a weakening process. Interestingly, these results contrast with the findings by Oliver Rajan (2008) who found more raising in words with antepenultimate stress, suggesting that stress pattern plays a different role in the Spanish of Colongo than in her data. An anonymous reviewer suggested that this difference in

stress pattern may be a result of the aspiration of /s/ in Puerto Rican Spanish as opposed to the lack of aspiration in Mexican Spanish, which is certainly an additional aspect that merits further investigation in the future.

The lexical category is a significant predictor for /o/ and /e/, with more raising in the group containing pronouns. However, it is a bit unclear as to why this is the case. 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 this case, since we do not see any clear differences. An anonymous reviewer commented that perhaps the difference has to do with the spontaneous nature of the conversations instead of speech produced in a lab, something that should be considered for future studies.

5.1 Weakening Hypothesis

The previous theories on vowel weakening (examined in section 2.3) propose several possible explanations for the raising of mid vowels to high vowels in unstressed positions and provide support for the idea that unstressed mid vowel raising, such as what we see in Colongo, is a weakening process. I suggest that unstressed mid vowel raising as a weakening process refers not only to a reduction in the number of vowel contrasts, but also includes a reduction in terms of duration. More raising is observed in contexts in which shorter duration has been found cross-linguistically; note, however, that I do not look specifically at duration in this study. I consider mid vowel raising and unstressed vowel devoicing (UVD) together under the larger category of vowel weakening, both coinciding with 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. When we consider 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). In the Colongo data, 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), since the contexts that lead to reduced duration correlate with more raising. Additional support for the mid vowel raising as a weakening process 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 2015).

Many of the factors that have proven to be significant for unstressed mid 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. We also discussed how Mexican Spanish is a variety that exhibits frequent vowel weakening in the form of UVD, and I found evidence of both devoicing and elision in my data. As a result, it is not surprising that we see evidence for another type of weakening process in the same dialect. Although I have focused on many similarities between

vowel raising and UVD, there are some differences between the two processes that should be pointed out. For instance, while studies show that UVD can occur in pre-tonic and tonic positions, there is no evidence of vowel raising in these 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, based on these differences I propose that we consider unstressed vowel raising as an instance of a separate vowel weakening process. In fact, 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.

We have also seen significant coarticulatory effects, especially from directly adjacent sounds, which 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. They also find that coarticulatory effects are more likely and greater when sounds are reduced in duration (see also Scarborough 2004), which goes hand in hand with the unstressed mid vowel weakening process.

6. Conclusions

Overall, the results from this study show that vowel raising in Michoacán is different from the vowel raising in Spain and Puerto Rico that has been more thoroughly studied. Not only is /e/ raising more frequent than /o/ raising, but it happens much more frequently than what has been found in other regions. For instance, in Puerto Rican Spanish, 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%. 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%. This comparison shows us that the raising rate for /e/ in Colongo is much higher than in previous studies and the raising rate for /o/ is much lower. However, if we compare the overall rate of raising, it is similar to what Holmquist found, but higher than what Oliver Rajan found in Puerto Rico. As an anonymous reviewer pointed out, Oliver Rajan (2018) proposes that vowel raising in Puerto Rican Spanish is "slowly disappearing" due to increased mobility while further studies are necessary to determine the trajectory of vowel raising in Colongo.

This thorough investigation has been fruitful for our understanding of the vowel raising process in Colongo. Exploring the phonetics and phonology interface has allowed for a more thorough explanation of the unique vowel raising that occurs in Colongo, Michoacán and contributes to our general understanding of the characteristics of the Spanish from the region. While many of the same independent factors found in Puerto Rico are significant in this variety, the direction of raising often differs (i.e. more /e/ raising in Colongo and more /o/ raising in Puerto Rico).

Additionally, I have provided support for viewing unstressed mid vowel raising in Colongo as a weakening process, especially based on results showing its similarity to other vowel weak-

ening processes, namely unstressed vowel devoicing. Some of the limitations of this study include the number of participants, the lack of the study of perception, and the need to examine both UVD and duration of the vowels for this particular variety. Future research on both UVD and duration in this dialect of Spanish and others would lend further support to the suggestion that unstressed mid vowel raising in Colongo should be viewed as a weakening process. An additional area for future research should be to study the perception of the mid vowels to determine which additional factors (besides F1 and F2) aide in the discrimination between the high and mid vowels. This would also help to explain the differences between the initial auditory analysis and the DAPC analysis. With the additional analyses proposed, the argument for weakening hypothesis suggested here can be strengthened.

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