An Acoustic Examination of Unstressed Vowel Reduction in Heritage Spanish

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1. Introduction

The Spanish vowel system is typically described as a simple, stable, five-vowel system that exhibits little variation based on lexical stress (Delattre, 1969; Hualde, 2005; Navarro Tomás, 1918). Many of the assumptions about the Spanish vowel system are based on impressionistic accounts of pronunciation or productions obtained from highly controlled speech samples (Delattre, 1969; Lope Blanch, 1972; Martínez Celdrán, 1995; Morrison, 2004; Navarro Tomás, 1918). Several recent acoustic descriptions of the Spanish vowels indicate, however, that there is considerably more variation within the system than previously believed (Delforge, 2008; O'Rourke, 2010; Marín Gálvez, 1995; Menke & Face, 2010; Servín & Rodríguez, 2001; Willis, 2005). More specifically, acoustic descriptions of both monolingual and bilingual Spanish vowel systems report the presence of varying types of unstressed vowel reduction in terms of quality and duration (Delforge, 2008; Marín Gálvez, 1995; Menke & Face, 2010; Willis, 2005). The goal of the present investigation is to determine the extent and manner in which the heritage Spanish vowel system exhibits unstressed vowel reduction by providing an in-depth acoustic analysis of semi-spontaneous speech data. The results of the acoustic analyses demonstrate that heritage speakers exhibit differences in vowel pronunciation as a consequence of lexical stress both in terms of vowel quality (acoustic distribution) and vowel quantity (duration). These findings contribute to the overall body of literature pertaining to Spanish vowel systems as well as offer one of the first acoustic descriptions of heritage Spanish vowels.

The present investigation is organized as follows. Section 2 includes a review of the literature pertaining to the Spanish vowel system, vowel reduction, and heritage speakers. The research questions guiding this study are presented in section 3, and the methodology is described in section 4. The results of the acoustic and statistical analyses are presented in section 5. Finally, section 6 provides the conclusions, discussion, and directions for future research.

2. Previous Literature

2.1. The Spanish vowel system

In comparison to the number of investigations focusing on Spanish consonants, considerably fewer studies have examined the acoustics of Spanish vowels, possibly resulting from the claim that Spanish vowels exhibit little variation and are fairly stable across dialects (Hualde, 2005; Navarro Tomás, 1918; Quilis & Esgueva, 1983). The Spanish vowel system is traditionally described as consisting of five pure monophthong vowels that are distinguished by three degrees of height and three degrees of backness (Martínez Celdrán, 1995; Navarro Tomás, 1918). Along the height dimension, vowels are organized as high (/i/ and /u/), mid (/e/ and /o/) and low (/a/). Along the front-back dimension, the /i/ and /e/ constitute the front vowels, /a/ is classified as the central vowel, and /o/ and /u/ are categorized as back vowels. In terms of the acoustic properties, the first and second formant frequencies serve to distinguish the Spanish vowels from one another (Martínez Celdrán, 1995). The

[*] I am extremely grateful to Erik Willis and two anonymous reviewers for their helpful comments and feedback on this work. I would also like to thank Kim Potowski for her assistance in subject recruitment and data collection. All errors are my own.

first formant frequency (F1) is the acoustic correlate of vowel height, and the second formant frequency (F2) is related to vowel backness. Figure 1 illustrates the organization and acoustic distribution of Spanish vowels produced by two monolingual female speakers of Mexican Spanish. The figure has been recreated using the un-normalized values reported in Servín and Rodríguez (2001) that were obtained from tonic vowels produced in a carrier phrase task.

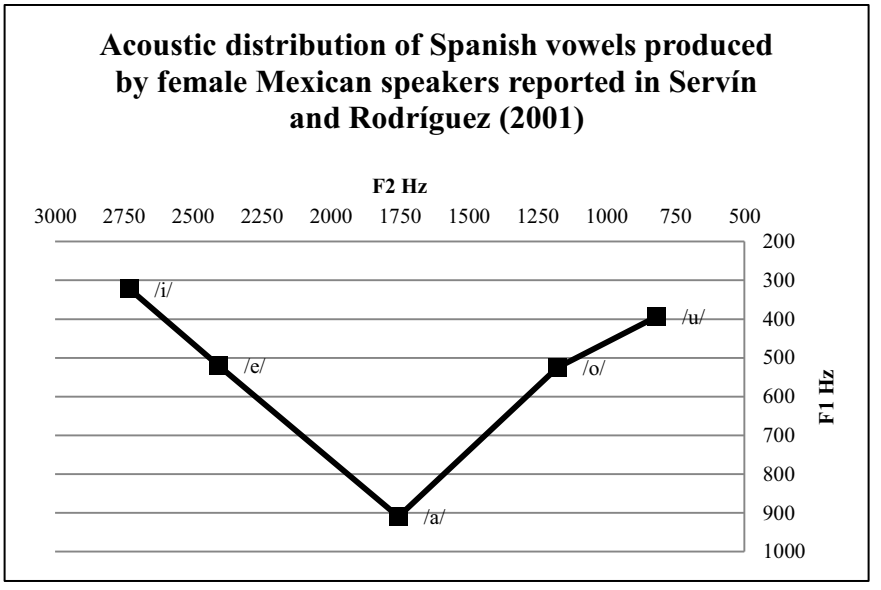

Figure 1. Chart of formant values reported in a study of Mexican Spanish vowels by Servín and Rodríguez (2001). The values are the average formant frequencies produced by two female speakers from Mexico City.

The shape of the vowel space presented in Figure 1 corresponds roughly to the description commonly found in the literature (Hualde, 2005; Navarro Tomás, 1918; Martínez Celdrán, 1995; Quilis & Esgueva, 1983). This organization stands in contrast to the shape of the vowel space produced by the heritage speakers in this study and presented in section 5.

2.2. Unstressed vowel reduction in Spanish

Despite the assumption of simplicity and stability, a number of investigations have examined the presence and degree of unstressed vowel reduction in different regional varieties of Spanish (Delattre, 1969; Delforge, 2008; Lope Blanch, 1972; Marín Gálvez, 1995; Matluck, 1952; Navarro Tomás, 1918; Quilis & Esgueva, 1983).[1] Traditional descriptions of the Spanish vowel system report little or no reduction (Delattre, 1969; Navarro Tomás, 1918; Quilis & Esgueva, 1983). Navarro Tomás (1918) described that unstressed vowels can take on a relaxed character, especially in word-final position or when in the penultimate syllable of a proparoxytone. The differences were described as being slight, however, and the reduction present in the Spanish system was significantly less than what is observed in languages such as English. Delattre (1969) corroborated this finding in an acoustic study of vowel reduction in Spanish, English, German, and French. Spanish exhibited the smallest degree of vowel quality reduction in the form of centralization, whereas English showed the greatest degree, with atonic vowels centralizing and reducing to the neutral vowel schwa. In an additional acoustic study, Quilis and Esgueva (1983) reported that atonic vowels had a slight tendency to occupy a more centralized location within the acoustic space, but that the differences in quality between tonic and atonic vowel productions were minimal overall.

[1] As will be explained in greater detail throughout this section, the term "reduction" has variable meanings. "Reduction" can be used to describe centralization of unstressed vowels toward schwa (Delattre, 1969), audible differences in quality ranging from decreased intensity and timbre to complete elision (Lope Blanch, 1972), devoicing (Delforge, 2008), and decreased duration (Marín Gálvez, 1995).

In contrast, a number of additional studies not only report the presence of unstressed vowel reduction in Spanish, but suggest that it can manifest itself in the form of differences in vowel quality, voicing characteristics, and duration (Delforge, 2008; Lope Blanch, 1972; Marín Gálvez, 1995). Several impressionistic accounts of Central Mexican Spanish reported greater degrees of reduction and even deletion of unstressed vowels that is influenced by the position of a vowel within the word and the surrounding consonantal context (Boyd-Bowman, 1952; Lope Blanch, 1972; Matluck, 1952). Lope Blanch (1972) specifically described that unstressed front vowels had the highest likelihood of reducing or deleting when followed by the voiceless fricative /s/. In contrast, Delforge (2008) argued against the notion of unstressed vowel reduction in terms of quality in her analysis of Andean Spanish. A closer examination of vowels via spectrographic analysis showed that unstressed /e/ and /o/ followed by /s/ actually devoiced as opposed to centralizing. Finally, in an analysis of Peninsular Spanish, Marín Gálvez (1995) reported significant differences in vowel duration based on lexical stress. His analysis of two male speakers' vowel productions obtained from a reading task revealed that atonic vowels were approximately 20% shorter than tonic vowels. The distinctions in length were found for all five phonemes.

Although the presence and degree of unstressed vowel reduction in monolingual varieties of Spanish is a topic of debate, the effect of lexical stress on Spanish-English bilingual and Spanish L2 learner vowel pronunciation is well-supported (Harris & Gries, 2011; Menke & Face, 2010; Stevens, 2011; Willis, 2005). A recent acoustic study of Spanish-English bilingual adults in the Southwestern United States, for example, presented evidence for the raising of /a/ in atonic syllables for at least one speaker (Willis, 2005). An investigation conducted by Menke and Face (2010), which analyzed vowels produced by L2 Spanish learners as well as Spanish-English bilingual adults, reported significant centralization of unstressed vowels. Nearly all atonic vowels produced by the L2 Spanish learner groups were significantly more centralized than their tonic counterparts, especially along the F2 dimension. The native bilinguals (i.e., L1 Spanish-English bilinguals) also showed some degree of centralization, but only /e/ and /u/ exhibited statistically significant differences in F2.

Studies of bilingual and L2 Spanish pronunciation have also revealed important differences between these populations and monolingual speakers with respect to vowel duration and speech rhythm. Learner and bilingual Spanish vowel duration tends to be longer than monolingual duration, possibly as a consequence of limited or lesser proficiency in Spanish (Harris & Gries, 2011; Stevens, 2011). In addition, bilingual speakers of English and Spanish have been shown to exhibit patterns of durational variability in their vowel productions that differ from what is documented for monolingual varieties. Thomas and Carter (2006) and Carter (2007), for example, reported that speakers of Hispanic English exhibited rhythmic patterns that were more syllable-timed (i.e., more "Spanish-like") than speakers of African American and Anglo American varieties of English.[2]

The previous research on unstressed vowel reduction in Spanish therefore suggests that both monolingual and bilingual/learner varieties of Spanish exhibit some degree of quality reduction, centralization, and shortened duration of atonic vowels. The goal of the present study is to further examine the topic of vowel reduction in Spanish by conducting an acoustic and statistical analysis of semi-spontaneous speech data. Unlike previous studies, however, this investigation examines a unique population of Spanish-English bilinguals known as heritage speakers.

2.3. Who are heritage speakers?

Heritage speakers of Spanish (hereafter HS), who are sometimes also referred to as *circumstantial* or *early* bilinguals, are differentiated from other bilingual populations by their 1) early exposure to the Spanish language and 2) limited access to formal education in the heritage language until later in life (Montrul, Foote, & Perpiñán, 2008; Valdés, 2005). Heritage speakers of Spanish are bilinguals who

[2] Spanish and English have traditionally been described as belonging to distinct rhythm classes: syllable-timed and stress-timed, respectively (Pike, 1945). Languages that have a wide variety of syllable types and exhibit considerable quality and quantity reduction of unstressed vowels, such as English, are traditionally classified as stress-timed (Ramus, Nespor, & Mehler, 1999). In contrast, languages that exhibit little unstressed vowel reduction and have less complex syllable structure, such as Spanish, are often classified as syllable-timed (Ramus et al., 1999). For additional information pertaining to rhythmic classification and the metrics used to determine rhythm class, see also Grabe and Low (2002) and Harris and Gries (2011).

were raised in the United States overhearing and often speaking Spanish within the home and community with parents and relatives, but most likely did not receive any formal literacy education in the language until high school or college (Rothman, 2007; Valdés, 2005). Thus, they often have advanced communicative and comprehension skills in Spanish, but may be less proficient in the formal oral and written registers. Despite variable proficiency in Spanish, however, HS tend to be proficient in, and possibly more comfortable or fluent in English: the primary language used in academic settings, social activities, and the workplace (Montrul et al., 2008).

A considerable amount of linguistic research on heritage populations has focused on describing effective pedagogy for HS, or on assessing HS morphosyntactic knowledge. Taken broadly, the general findings of these studies indicate that HS populations differ from age-matched monolinguals, fluent bilingual speakers, and *late* L2 learners, and thus should be examined separately from these populations (Kagan, 2005; Montrul et al., 2008; Potowski, Jegerski, & Morgan-Short, 2009; Rothman, 2007; Valdés, 2005; Valdés & Geoffrion-Vinci, 1998). That is, while HS share certain aspects of acquisition with L2 learners (e.g., transfer errors from the majority language), they have also been found to outperform late L2 learners, but not native monolinguals, on vocabulary tasks, grammaticality judgment tasks, and their perception and repetition of sentences in noise (Au, Oh, Knightly, Jun, & Romo, 2008; Montrul et al., 2008).

Despite the frequent claim that overhearing and speaking a language early in life results in more native-like pronunciation (Au et al., 2008; Oh, Jun, Knightly, & Au, 2003), considerably few studies have directly examined HS pronunciation. Although they do not specifically examine HS as defined here, investigations conducted by Flege (1991) and Flege and Eefting (1987) indicated that early bilinguals, who are somewhat similar to HS with respect to age of exposure to Spanish, exhibited intermediate Voice Onset Times (VOT) that fell somewhere between those produced by L2 learners and monolingual speakers. An additional study conducted by Knightly, Jun, Oh, and Au (2003) found that HS of Spanish approximated native-speaker norms of VOT and lenition but differed significantly from the late L2 Spanish learners. The HS were also rated as more "native-sounding" than the late L2 learners, but were not quite as highly rated as the true native Spanish speakers who took part in the same reading task.

To summarize briefly, the majority of the investigations which specifically examine HS of Spanish have focused on their knowledge and usage of a variety of morphosyntactic structures, or have proposed unique instructional strategies for this population. That there are considerably fewer studies which examine heritage speakers' pronunciation motivates the need for a closer examination of the HS phonetic/phonological system. One area that is deserving of further investigation is the vowel system, due in part to the fact that HS of Spanish must employ two very different vowel systems (i.e., English and Spanish) throughout their daily lives. An additional motivating factor is that although a number of studies have examined Hispanic English vowel pronunciation (e.g., Carter, 2007; Fought, 1999; Frazer, 1996; Godinez & Maddieson, 1985; Konopka & Pierrehumbert, 2008; Roeder, 2010a, 2010b; Thomas, 2001; Wolfram, Carter, & Moriello, 2004), no study to date has examined the Spanish vowel system of heritage Spanish speakers.

3. Research Questions

The review of the literature presented in section 2 motivates the need to further investigate and characterize unstressed vowel reduction in heritage Spanish via acoustic methodology. The present investigation is therefore guided by the following research questions:

1. Does lexical stress impact heritage Spanish vowel quality (F1 and F2) and quantity (duration)? Do tonic and atonic vowels exhibit minimal quality and quantity differences as is argued for many monolingual varieties of Spanish, or do HS vowel productions exhibit stress differences that have been observed in bilingual and learner varieties?

2. If unstressed vowel reduction is present in the HS system, how can it be characterized (i.e., as quality reduction, centralization towards schwa, devoicing, and/or shortened duration)?

These two questions will be addressed via systematic acoustic and statistical analyses of vowels produced in semi-spontaneous speech data, all of which are described in greater detail in section 4.

4. Methodology

4.1. Participants

Thirteen female HS between the ages of 18 and 22 took part in this study. Twelve of the speakers were of Mexican descent and one was of Puerto Rican descent. Eleven participants were born in the United States, whereas two were born in Mexico and moved to the United States at the ages of two and six years. All participants reported that they had grown up in Spanish-speaking communities in the Chicago area. At the time of the investigation, each participant was either currently enrolled in (n = 5), or had recently completed (n = 8), an intermediate-level Spanish course designed for HS. Four participants indicated that they received formal instruction in the Spanish language during preschool or elementary school. The remaining nine participants did not begin formally studying Spanish until high school or college. Language background and use questionnaires indicated that all of the participants spoke both Spanish and English on a daily basis, considered themselves to have communicative proficiency in both languages, and self-reported similar speaking, writing, and listening abilities in Spanish. English was used primarily in academic and work-related settings, for communicating with non-Hispanic friends and classmates, and for watching television and listening to music. Spanish was most frequently spoken at home with family, with friends within the community, with other Spanish-speaking acquaintances in the workplace, and sometimes for watching television and movies. Additional information about the participants in this study is presented in Appendix A.

4.2. Experimental design

The vowel productions analyzed in this investigation were obtained from a semi-spontaneous picture identification task.[3] The task was presented to the participants in the form of a memory game, and they were given a scenario to help contextualize the lexical items they would be asked to say. It consisted of two phases: a training phase and an actual task phase. Before the actual task began, participants were familiarized with the names of the objects they were going to see. They were instructed to say out loud the name and the number of each object presented on the slide. The first few letters of the object name were provided to help eliminate any ambiguity as to what the object was and to ensure that each speaker produced the word containing the target vowel. The sample slide presented in Figure 2 is intended to prompt the response *tres plátanos* 'three bananas.'

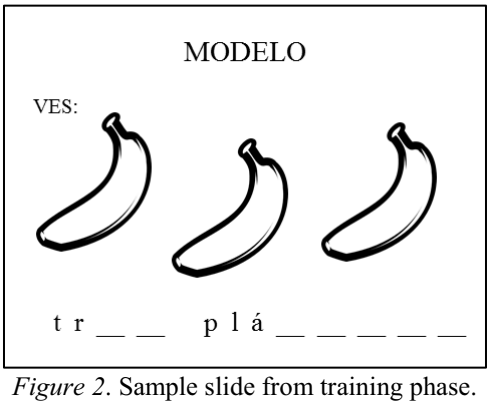

Figure 2. Sample slide from training phase.

[3]This investigation is part of a larger study which examined several linguistic, stylistic, and individual variables. The entire experiment consisted of a language background questionnaire, a cultural sensitivity activity (Cushner, 1986), and a grammar proficiency test (Geeslin & Gudmestad, 2010). Each participant's score on the grammar proficiency test is included in Appendix A. In addition to the semi-spontaneous speech task described in section 4.2, participants also completed a narrative task and a carrier phrase task. The entire experiment took approximately one hour to complete.

Once the participants were familiarized with the objects, they proceeded to the actual task. The participants were told that they were attending a surprise party and needed to report who had just arrived at the party and what they brought with them as a gift. The participants were given a model, presented in Figure 3, which instructed them to say the name of the person who brought the item, what the item was, and how many they brought. The picture below prompts the response *Enrique trajo tres plátanos* 'Enrique brought three bananas.' Unlike the slides in the training phase, the slides presented in the task phase did not include letters and blanks at the bottom of the screen.

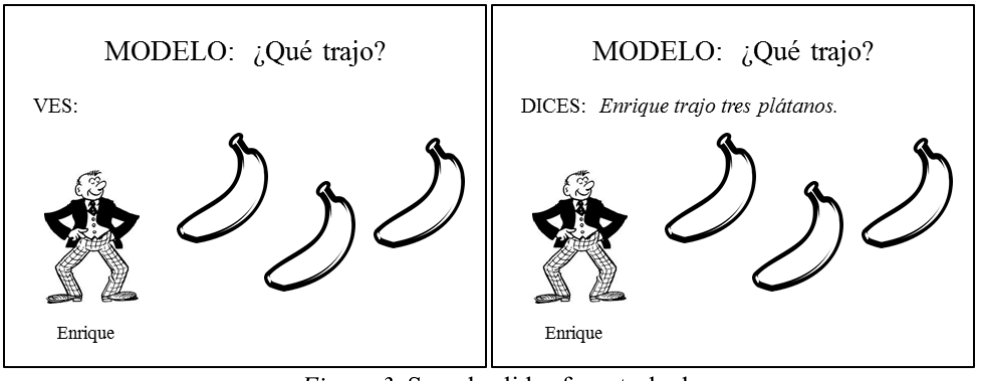

Figure 3. Sample slides from task phase.

The picture identification task was balanced across stress context and syllable type for all five vowels.[4] The organization of the word list resulted in a potential total of 80 vowels per speaker. A list of the words utilized in this task is presented in Appendix B.

Upon finishing the picture identification task, all participants completed a language background questionnaire that inquired about their daily usage of English and Spanish. In addition, all participants completed a short grammar proficiency activity consisting of 25 multiple choice questions (Geeslin & Gudmestad, 2010). The purpose of the grammar proficiency activity was to ensure that the participants had comparable proficiency in Spanish. Finally, each participant was asked to complete Cushner's (1986) Inventory of Cross-Cultural Sensitivity (ICCS).[5]

4.3. Stimulus presentation and data analysis

The experiment was carried out in a quiet office in which only the investigator and the participant were present. The recordings were made using a Shure head-mounted microphone and a USBPre microphone interface that was run through a Dell Netbook. The stimuli were presented via Microsoft Power Point using a Hewlett Packard G62 laptop computer. Each participant completed the task in approximately 10 minutes.

The target vowels were first segmented out of the running speech using a chop and label procedure in Praat Software (Boersma & Weenink, 2010). Two automated scripts extracted the first and second formant frequencies (F1 and F2) at the mid-point of each vowel and the duration of each vowel (Lennes, 2002, 2003). The boundaries for each vowel were determined by various acoustic cues, including increased wave amplitude, periodicity in the wave form, and onset of clear formant structure in the spectrogram. The formant values and durations extracted with the Praat scripts were checked by the investigator and an additional trained phonetician to ensure the accuracy of the measurements. Vowel tokens that were produced with creaky voice and those in which no clear formant structure was present were excluded from the analysis.

[4] The effect of syllable type will not be discussed in the present study.

[5] The ICCS questionnaire consists of a series of statements in English. Each participant was asked to indicate how strongly she agreed or disagreed with each statement. The scores on this activity will not be discussed in the present study.

4.4. Statistical analysis

In order to examine the effects of lexical stress on HS vowel production, the raw formant values and vowel duration measures were submitted to a Mixed Linear Model using SPSS version 19. Three separate models were designed and run on the three dependent variables: F1, F2, and Duration. The independent variables in each model were Vowel and Stress, and a full factorial model was created in order to examine the interaction between Vowel and Stress. The random effect of Speaker was included to control for individual variation in formant frequencies and speaking rate.[6]

5. Results

Prior to discussing the results of the Mixed Linear Models conducted on F1, F2, and duration, an overview of the data is presented in Table 1. This table includes the estimated marginal means of F1, F2, and duration that were calculated by the statistical models, as well as the number of vowels analyzed in each stress category.

Table 1

Mean formant values and duration of tonic and atonic vowels produced in a semi-spontaneous speech task by heritage speakers of Spanish

Vowel	Stress	Number of cases	F1 (Hz)	F2 (Hz)	Duration (ms)
/i/	atonic	66	383.85	2377.68*	60.86*
	tonic	102	389.44	2477.87*	72.01*
/e/	atonic	132	495.79*	1868.53*	58.88*
	tonic	130	566.27*	2026.65*	87.39*
/a/	atonic	119	718.85*	1571.76	74.63*
	tonic	149	793.36*	1593.84	102.88*
/o/	atonic	72	538.41*	1214.06*	63.27*
	tonic	69	581.42*	1112.55*	96.21*
/u/	atonic	70	428.85	1321.94*	54.35*
	tonic	93	423.50	1156.94*	87.08*

Note. Values represent the estimated marginal means calculated by the statistical model and not the raw averages. Asterisks indicate statistically significant differences between tonic and atonic vowel productions.

The statistical results for vowel quality (F1 and F2) are presented in section 5.1, followed by the results for vowel duration in section 5.2. Section 5.3 presents the findings of two additional Mixed Linear Models which examined the relationship between vowel quality and duration. A summary of the results is presented in section 5.4.

5.1. Vowel quality

The Mixed Linear Model conducted with F1 as the dependent variable indicated a significant main effect of Vowel ($F(4, 980.16) = 1394.71$, $p < .001$), a main effect of Stress ($F(1, 980.20)$

[6] The raw formant values and durations were submitted to the analysis, and no other traditional normalization procedure was conducted. All of the participants were adult females who exhibited similar F1 and F2 ranges. In addition, prior statistical tests were conducted with individual data as well as with combined, normalized data to ensure that the lack of a formal normalization procedure would not yield unreliable results. Both the individual analyses and the statistics conducted with normalized formant values yielded the same results as those presented in section 5.

= 100.47, $p < .001$), and a significant Vowel by Stress interaction ($F(4, 980.24) = 20.37$, $p < .001$).[7] Figure 4 represents the overall tonic and atonic vowel distribution within the acoustic space. A more detailed interpretation of the statistics is provided following the figure.

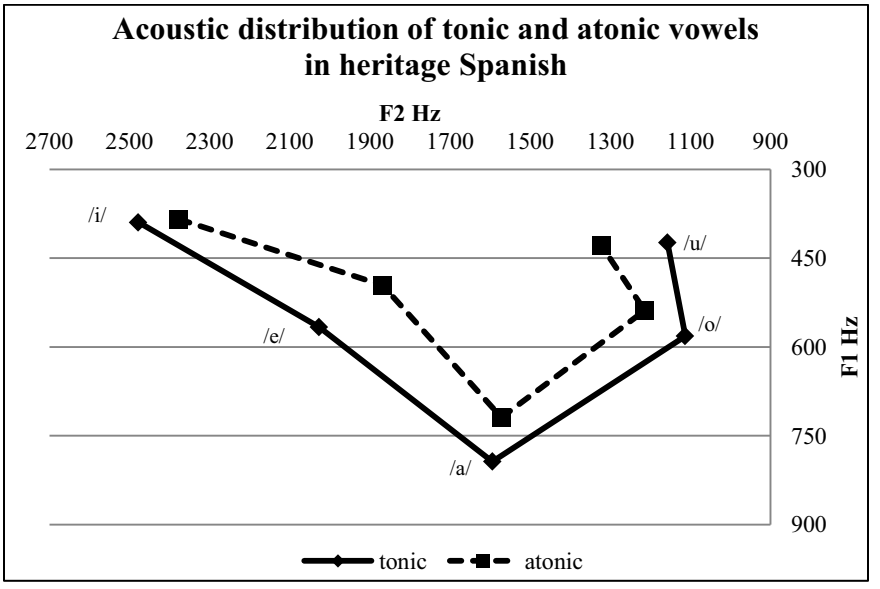

Figure 4. Atonic and tonic vowel productions obtained from a picture identification (semi-spontaneous) task completed by thirteen female heritage Spanish speakers. The solid line represents the tonic vowel space and the dashed line represents the atonic vowel space.

The main effect of Stress indicated that overall, the F1of atonic vowels was significantly lower (513.14 Hz) than that of tonic vowels (550.79 Hz). This result indicates that vowels produced in unstressed syllables occupied a higher position within the acoustic space than those produced in stressed syllables. An examination of the significant interaction between Vowel and Stress via pairwise comparisons with a Bonferroni adjustment indicated that the difference between tonic and atonic vowel productions was particularly robust for the non-high vowels /e/, /a/, and /o/ ($p < .001$ for all three vowels). Thus, atonic /e/, /a/, and /o/ were produced significantly higher in the acoustic space than their tonic counterparts. In contrast, the tonic and atonic productions of /i/ and /u/ were not found to differ significantly with respect to F1 (for /i/, $p = .534$; for /u/, $p = .552$).

The Mixed Linear Model conducted with F2 as the dependent variable indicated a significant main effect of Vowel ($F(4, 980.30) = 1315.89$, $p < .001$) and a significant Vowel by Stress interaction ($F(4, 980.43) = 24.96$, $p < .001$).[8] A closer examination of the significant interaction via pairwise comparisons with a Bonferroni adjustment showed that all vowels except for /a/ exhibited significant movement towards the center of the vowel space when produced in atonic syllables. The front vowels /i/ and /e/ were characterized by significantly lower F2 values (i.e., farther back in the acoustic space) in atonic syllables as compared to those produced in tonic syllables (for /i/, $p = .001$; for /e/, $p < .001$). The inverse was true for the back vowels /o/ and /u/, which showed significantly higher F2 values (i.e., farther front in the acoustic space) when atonic as compared to tonic (for /o/, $p = .001$; for /u/, $p < .001$). The differences in vowel backness can also be observed in Figure 4.

The results of the acoustic and statistical analysis of vowel quality therefore show that atonic vowels differ from tonic vowels in terms of both height and backness. These findings differ from

[7] The main effect of Vowel indicated that, as expected, the five Spanish vowels were distinguished by three degrees of height. This finding is consistent with previous acoustic studies of Spanish vowels (Martínez Celdrán, 1995) and will not be discussed further.

[8] The main effect of Vowel for F2 indicated that HS Spanish vowels were distinguished from one another with respect to backness. This is consistent with previous descriptions of Spanish vowel systems (Martínez Celdrán, 1995), and will not be discussed further.

traditional accounts of monolingual Spanish vowel pronunciation, but are consistent with acoustic descriptions of bilingual Spanish vowel systems reported in Willis (2005) and Menke and Face (2010). The raising of /a/ reported in the present investigation is similar to that described by Willis (2005) for Southwest Spanish. There also appears to be a slightly greater effect of stress on F2 given that four of the five vowels showed significant differences along the front-back dimension but only three differed with respect to height. Menke and Face (2010) also reported that lexical stress had a greater effect on F2 than on F1 in the L2 learners of Spanish and adult Spanish-English bilingual productions analyzed in their study. Interestingly, however, the atonic vowels produced by HS did not centralize in the direction of schwa. This lack of centralization will be discussed further in section 6.

5.2. Vowel quantity

The Mixed Linear Model conducted on vowel Duration revealed a significant main effect of Vowel ($F(4, 980.42) = 31.38$, $p < .001$), a significant main effect of Stress ($F(1, 980.50) = 312.89$, $p < .001$), and a significant Vowel by Stress interaction ($F(4, 980.57) = 6.13$, $p < .001$).[9] The average duration of tonic and atonic vowels is depicted in Figure 5. Further discussion of the statistical results is provided following the figure.

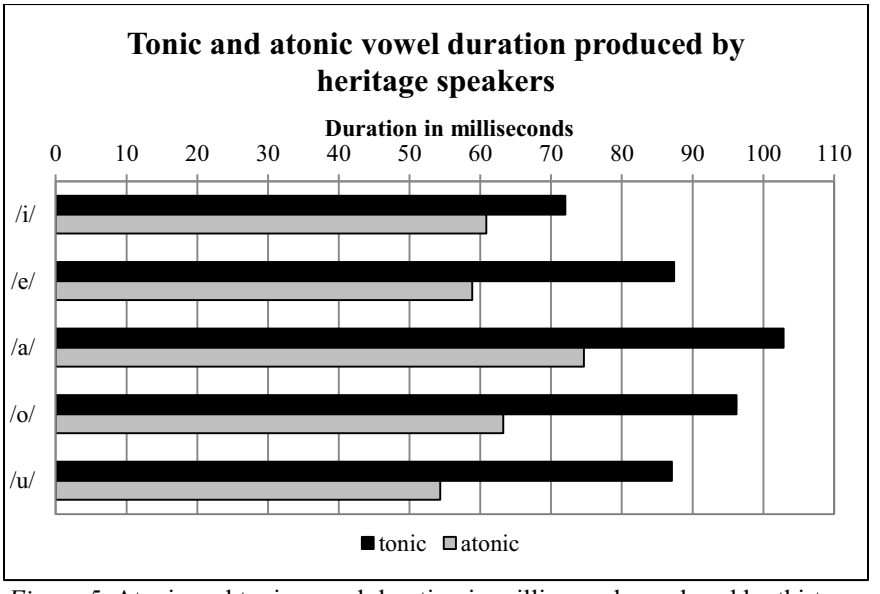

Figure 5. Atonic and tonic vowel duration in milliseconds produced by thirteen female heritage speakers of Spanish in a semi-spontaneous speech task. The black bars represent the duration of tonic vowels, and the gray bars represent atonic vowel duration.

The main effect of Stress indicated that overall, the atonic vowels were significantly shorter in duration than the tonic vowels (atonic = 62 ms, tonic = 89 ms). The significant Vowel by Stress interaction indicated that the effect of stress was larger for some vowels than for others. Pairwise comparisons with a Bonferroni adjustment showed that all atonic vowels were significantly shorter than their tonic counterparts (for all vowels except for /i/, $p < .001$). The high front vowel /i/ showed the smallest durational difference as a result of stress, but the effect was still statistically significant (atonic = 60.86 ms, tonic = 72.01 ms; $p = .002$).

The results of the analysis of vowel duration revealed greater durational differences between tonic and atonic vowel productions than those described by Navarro Tomás (1918), but closely resemble the

[9] The main effect of Vowel indicated that vowel duration varied as a function of height. When averaging across stress types, the low vowel /a/ had the longest duration (89 ms) followed by the mid vowels /e/ (73 ms) and /o/ (80 ms). The high vowels were the shortest in length (/i/ = 66 ms, /u/ = 71 ms). This finding is consistent with the results of Marín Gálvez (1995), who also reported that vowel duration decreased as vowel height increased.

findings of Marín Gálvez (1995) for Peninsular Spanish. Like the findings reported in Marín Gálvez, the HS examined in the present study exhibited intrinsic vowel duration and produced atonic vowels that were significantly shorter in duration than tonic vowels. For comparative purposes, Figure 6 presents the tonic and atonic vowel duration of the HS analyzed in the present study along with the monolingual duration reported in Marín Gálvez.

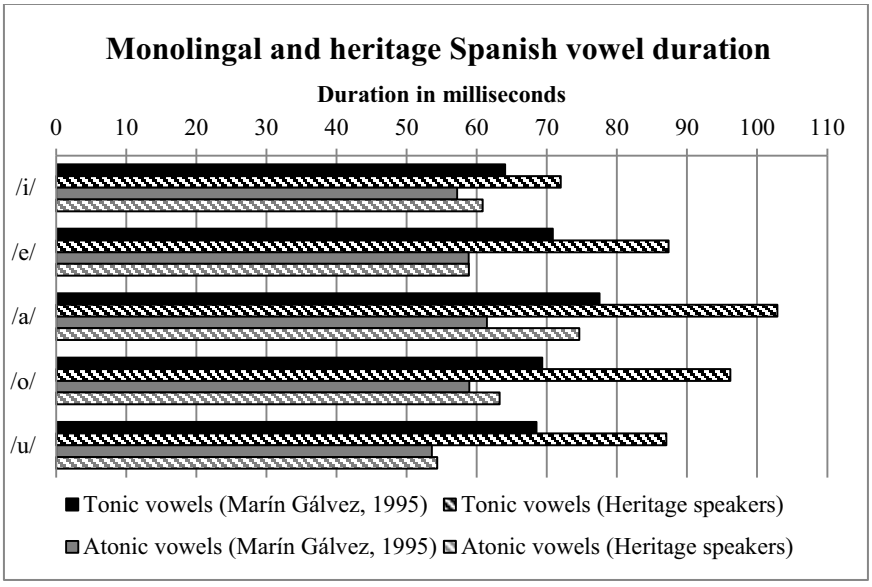

Figure 6. Comparison of monolingual and heritage Spanish vowel duration. The monolingual values were obtained from a reading task completed by two male speakers of Peninsular Spanish (Marín Gálvez, 1995). The heritage Spanish data were obtained from a picture identification task completed by 13 female HS. The solid bars represent the monolingual duration and the patterned bars correspond to the HS vowel duration. The black bars represent tonic vowel duration while the gray bars represent atonic vowel duration.

Despite their similarities, a closer examination of the heritage and monolingual vowel duration presented in Figure 6 reveals two important differences between the varieties. First, the HS tonic and atonic vowels were considerably longer overall than those reported for monolingual Spanish speakers. The monolinguals in Marín Gálvez (1995) produced tonic vowels with an average duration of 70 milliseconds and atonic vowels with a duration of 58 milliseconds, whereas the average duration of HS tonic vowels was 89 milliseconds and atonic vowels was 62 milliseconds. Second, the degree of vowel reduction was also greater for HS than for the monolingual speakers. Marín Gálvez reported that atonic vowels were approximately 20% shorter than their tonic counterparts. The HS analyzed in this study, however, showed a proportion of reduction that is closer to 30% overall. Thus, although both groups of speakers exhibited similar patterns of duration, the HS vowels were considerably longer overall and the proportion of reduction between atonic and tonic HS vowels was greater than that reported for the monolingual speakers.

5.3. Assessing the relationship between vowel quality and duration

Thus far, the results presented in sections 5.1 and 5.2 suggest that HS of Spanish exhibit unstressed vowel reduction in terms of quality and duration. There is some possibility, however, that vowel quality and duration are not independent of one another. That is, the quality differences observed between the tonic and atonic vowels could be due, in part, to the fact that atonic vowels were shorter in duration and therefore did not have sufficient time to reach their phonetic targets. In order to examine the relationship between vowel quality and duration, two additional Mixed Linear Models (one with F1 as the dependent variable and one with F2 as the dependent variable) were conducted, including Stress as an independent variable and Duration as a covariate. These analyses, which were

split by vowel, assess the extent to which stress-induced vowel quality differences remain when the influence of duration has been factored out.

The results of both statistical models revealed findings that were nearly identical to those presented in section 5.1. That is, even after adjusting for duration, the differences in vowel height and backness remained significant. With respect to F1, atonic /e/, /a/, and /o/ were still produced with significantly lower F1 values (i.e., significantly higher in the acoustic space) than their tonic counterparts (for /e/, $F(1, 248.75) = 62.34$, $p < .001$; for /a/, $F(1, 254.83) = 56.34$, $p < .001$; for /o/, $F(1, 128.47) = 13.84$, $p < .001$). In contrast, the atonic and tonic high vowels did not differ significantly with respect to F1 (for /i/, $F(1, 154.54) = .029$, $p = .865$; for /u/, $F(1, 154.08) = 1.54$, $p = .215$).

The additional statistical analysis conducted with F2 confirmed that atonic vowel productions differed significantly from tonic productions even after adjusting for the influence of duration. The findings were significant for /i/ ($F(1, 154.19) = 11.73$, $p = .001$) and /e/ ($F(1, 248.74) = .41.53$, $p < .001$), indicating that the atonic productions of these vowels exhibited significantly lower F2 values (i.e., farther back in the acoustic space) than their tonic counterparts. The F2 values of the atonic back vowels were significantly higher (i.e., farther front in the acoustic space) than the F2 of tonic back vowels (for /o/, $F(1, 132.06) = 14.34$, $p < .001$; for /u/, $F(1, 153.75) = 10.50$, $p = .001$). The effect of lexical stress on the central vowel /a/ was not found to be significant ($F(1, 258.11) = .000$, $p = .992$).

Combined, the results of the additional statistical analyses indicate that atonic vowel quality differed significantly from tonic vowel quality even after accounting for the influence of duration. Thus, the reduced quality was not a consequence of shorter vowel length.

5.4. Summary of results

The acoustic analyses of HS vowels described in the previous sections indicate the presence of unstressed vowel reduction in terms of quality and quantity. With respect to quality, atonic vowels were found to occupy a more centralized position within the vowel space when compared to their tonic counterparts. In particular, the non-high vowels /e/, /a/, and /o/ were characterized by significantly lower F1 values (i.e., were produced higher in the vowel space) when they were produced in atonic syllables. All atonic vowels except for /a/ showed movement toward the center of the vowel space along the F2 dimension, although there was no evidence of centralization toward schwa. Atonic vowels were also significantly shorter in duration than tonic vowels, and this difference was significant for all vowels. Subsequent analyses indicated that the differences in vowel quality between tonic and atonic vowels remained even when the potential influence of duration was taken into consideration.

6. Discussion and Conclusions

The results of this investigation offer insight into the organization of the HS vowel system and show that lexical stress significantly affects the way in which vowels are pronounced in this variety of Spanish. The finding that vowel quality was affected by stress is consistent with descriptions of Mexican Spanish vowel reduction (Lope Blanch, 1972) and bilingual quality reduction (Menke & Face, 2010; Willis, 2005), but conflicts with traditional descriptions of monolingual Spanish vowel systems (Navarro Tomás, 1918; Quilis & Esgueva, 1983). The results of the analysis of duration showed that atonic vowels were significantly shorter than tonic vowels, which corroborates the findings of Marín Gálvez (1995). A closer examination of the values reported in this study, however, indicated that HS vowels were longer than those produced by the monolingual speakers in Marín Gálvez, and that HS atonic vowels showed a larger proportion of reduction than previously reported.

The question then arises as to what is the cause of the unstressed vowel reduction in this bilingual variety. One of the most logical explanations is that these speakers are also proficient in English. As described previously in section 2, English and Spanish differ considerably in terms of the size of their vowel inventories and in the way that they resolve stress differences. Delattre (1969) showed that the amount of centralization of unstressed vowels in English was significantly greater than that observed in Spanish. Thus, the reduction of unstressed vowels observed in HS speech could possibly be due to the integration of characteristics from English into the Spanish system. Given that research on bilingual populations supports the formation of a modified and intermediate system of pronunciation for bilingual speakers (Flege & Eefting, 1987; Knightly et al., 2003; Menke & Face, 2010; Willis,

2005), it is likely that contact with English plays some role in the formation and organization of the HS vowel system.

Nevertheless, the quality and quantity reduction exhibited by the HS in this study is not consistent with what might be expected if English contact were the sole explanation. Although atonic vowels were produced less peripherally than their tonic counterparts, they were not centralized in the direction of schwa. In fact, the atonic productions of /e/ and /o/, although more centrally positioned along the F2 dimension, were actually *raised* as opposed to lowering towards the location of a neutral vowel. Furthermore, although HS vowel duration differed from the monolingual data presented in Marín Gálvez (1995), the longer duration and greater proportion of reduction observed in heritage Spanish could be attributed to differences in regional variety (i.e., Peninsular vs. Mexican) and task (i.e., reading text vs. picture identification), and not to English influence.

Also important to address is that even monolingual varieties, and especially Mexican Spanish, exhibit the reduction of unstressed vowels (Boyd-Bowman, 1952; Lope Blanch, 1972; Matluck, 1952). It is possible that the quality and durational differences produced by this group of HS, all but one of whom are of Mexican descent, is actually attributed to their having integrated this characteristic of the heritage Spanish variety into their speech. Several of the participants indicated that their parents originated from regions within Mexico in which unstressed vowel reduction has been documented. If the input that these bilinguals received during childhood and adolescence exhibited reduction, it is conceivable that this characteristic is reflected in their speech as adults.

In order to determine the primary cause of unstressed vowel reduction and attempt to tease apart the two potential influencing factors, the vowel productions from several other groups of speakers need to be examined. First, it would be necessary to analyze the pronunciation of the parents of the HS who participated in this study, as well as monolingual speakers of Spanish from similar dialect regions. An analysis of the English vowel productions of the HS in this study would permit comparisons between the degree of unstressed vowel reduction in their English and in their Spanish. Finally, an examination of the English vowel pronunciation of monolingual English speakers from the Chicago area would allow for a complete analysis of the HS vowel system. The combination of these analyses would offer insight into which characteristics of HS vowel pronunciation are attributable to language contact with English, and which are the result of the type of Spanish input they received throughout their lives. It is likely that both factors play some role in the formation of the HS linguistic system, but it is not possible to determine exactly how until additional groups of speakers are analyzed.

In conclusion, the present study provides a detailed, acoustic account of the effect of lexical stress on HS vowel production. By analyzing these speakers' productions acoustically as opposed to impressionistically, this study offers concrete evidence of unstressed vowel reduction that had not been quantified until now. As only one group of speakers were included in the analysis, however, it is not possible to arrive at a definitive conclusion as to what caused unstressed vowels to reduce in this variety. Regardless, this investigation provides further evidence of a unique system of bilingual vowel pronunciation. It also serves as an important first step in understanding how the HS phonological system is organized, providing baseline measures of pronunciation that can be compared to future analyses of monolingual, bilingual, and L2 learner Spanish vowel systems.

Appendix A: Participant demographic information

Participant ID	Age	Country born	Parents' city/country of heritage	Native language	Time spent studying Spanish	Age when started studying Spanish	Score on grammar test
1F	19	USA	Mexico, D.F.	Spanish	1 year college	18	20
2F	NR	USA	Mexico	English	1 year college	20	14
3F	19	USA	Mexico	English	1 year elementary school; 1 year college	8	22

4F	18	USA	Puerto Rico	English and Spanish	2 years high school; 2 semesters college	16	21
5F	20	USA	Mexico	Spanish	4 years high school; 1 year college	14	19
6F	22	USA	Mother - D.F. Father - Jalisco	Spanish	2 years preschool; all throughout high school and college	5	21
7F	21	USA	Mother - D.F. Father - Michoacán, Mexico	Spanish	No response	No response	19
8F	21	Mexico. Moved to U.S. at age 2.	Mexico, D.F.	English	1 year high school; 3 semesters college	17	21
9F	22	USA	Mexico	Spanish	Bilingual preschool and 3rd grade; two years high school and college	4	21
10F	21	Mexico. Moved to U.S. at age 6.	Mexico, D.F.	Spanish	Bilingual preschool; high school; 3 semesters college	4; 17	25
11F	19	USA	Mexico, D.F.	Spanish	2 semesters college	18	18
12F	19	USA	Mother- Chicago, IL Father- Guanajuato, Mexico	English	4 years high school; 2 semesters college	17	19
13F	19	USA	Jalisco, Mexico	Spanish	4 years high school; 2 semesters college	15	23

Note. The highest maximum score on the grammar proficiency test is 25 points. The average score on this activity was 20.23 points.

Appendix B: Words used in semi-spontaneous speech task

/a/
Tonic- lápiz, pescado, llaves, taza, cucharas, máscaras, cáscaras, durazno, tanque
Atonic-paquete, café, avispa, espaguetis, avestruz, mariscos, tostador
/e/
Tonic-espaguetis, bacteria, pasteles, peces, esqueletos, espejos, panqueques, bistec, insectos, césped
Atonic- películas, lechugas, revistas, pelota, esqueletos, pescado, espaguetis, espejos, escobas
/i/
Tonic- películas, cursiva, cuchillos, piscinas, oxígeno, avispas, revistas, mariscos
Atonic- piscinas, bicicleta, chicharrones, bistec, insectos, cristal
/o/
Tonic- chicharrones, osos, escobas, langostas, ostras, tostador
Atonic- fotografías, autobuses, tostador, oxígeno
/u/
Tonic- lechugas, luces, uvas, estufa, burbujas, autobuses, fútbol, avestruz
Atonic- cuchillos, cucharas, judías verdes, cursiva, durazno, burbujas

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Selected Proceedings of the 15th Hispanic Linguistics Symposium

edited by Chad Howe, Sarah E. Blackwell, and Margaret Lubbers Quesada

Cascadilla Proceedings Project Somerville, MA 2013

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ISBN 978-1-57473-457-7 library binding

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Ronquest, Rebecca E. 2013. An Acoustic Examination of Unstressed Vowel Reduction in Heritage Spanish. In *Selected Proceedings of the 15th Hispanic Linguistics Symposium*, ed. Chad Howe et al., 157-171. Somerville, MA: Cascadilla Proceedings Project. www.lingref.com, document #2882.