

Article

Spanish in Albuquerque, New Mexico: Spanish-English Bilingual Adults' and Children's Vocalic Realizations

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Abstract: This study explores vocalic production and variation in 29 Spanish-English bilingual children and adults from Albuquerque, New Mexico. Linear mixed-effects models analyzed the effects of lexical stress, word position, phonetic context, Spanish use, and lexical frequency on the F1 (height) and F2 (frontedness) values of 2041 /i e a o u/ vowels. Importantly, results show that /u/ fronting is pervasive in both children and adults' speech, but in contrast to adults' more general /u/ fronting, children's Spanish use also predicted atonic /u/ fronting. Expanding the range of data to include children also showed that children's realizations displayed a generalized stress effect, whereby the atonic space was condensed compared to the tonic space. The generalized stress effect was absent among the adults. Changes in the degree of phonetic convergence between the adults and children are attributed to acquisitional paths and demographic changes in their community.

Keywords: phonetics; bilingualism; child language; vowel spaces



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1. Introduction

The body of acoustic work on adult Spanish heritage speakers' phonetic and phonological patterns has grown substantially (see [Ronquest and Rao 2018](#) for a review), but acoustic research on child heritage Spanish speakers' phonetic and phonological development in the United States has been less abundant ([Menke 2010, 2015, 2018](#)). Most researchers are in agreement that heritage speakers' Spanish phonetic patterns can show evidence of phonetic convergence with English-like sound patterns ([Blair and Lease 2021](#); [Henriksen 2015](#); [Ronquest 2012](#)), but it is undetermined the degree of phonetic variation that is shared between child and adult heritage speakers in the same community. Thus, the present study adds to this body of phonetics-phonology research on US Spanish heritage speakers by studying the concomitant effects of established and novel variables predicting vocalic variation in children and adults.

The effects of lexical stress and Spanish use have always been of interest in this line of research, but frequency variables have yet to make an appearance. Already, it is established that frequency measures contribute to our understanding of phonetic variation, and specifically that highly frequent words and phrases undergo greater phonetic reduction than less frequent items ([Alba 2008](#); [Bybee 2001](#)). Therefore, the present study includes a lexical frequency measure to better describe vocalic variation among Spanish heritage speakers. This will also be the first time that a lexical frequency variable is used to examine Spanish-English bilingual children's vocalic development.

In addition to contributing new variables and populations to studies among Spanish-English bilinguals who have grown up in regions where Spanish is not the societally dominant language, the present study contributes an account of vocalic variation to current models of early bilinguals' phonetic development ([Fabiano-Smith and Goldstein 2010](#); [Menke 2010](#)). These models have posited that bilingual children's linguistic development can be delayed, accelerated, display transfer between their two languages, but that bilinguals maintain distinct phonological systems for each language. The latter claim had been

supported by an absence of lexical stress effects among bilingual children in the Southwest. However, as we will see in the present study on child heritage speakers in Albuquerque, New Mexico, the lack of phonetic convergence in bilingual children's vocalic patterns is not homogenous. In light of the differences, it will instead be suggested that researchers should consider how demographic measures and community language practices can predict and influence children's acquisitional paths.

1.1. The Speech Community—Albuquerque, New Mexico

The present study focuses on the Spanish spoken in Albuquerque, the largest city in Bernalillo county and in New Mexico. Just under a quarter of New Mexico's total population resides here. While other languages, such as Navajo and Thai, are spoken in the county, monolingual and bilingual Spanish-English speakers constitute the largest percentage of the population. In a city of 559,374 individuals, 21.97% report speaking Spanish in the home (US Census Bureau 2019b). The lexical items recorded for Albuquerque's Spanish speakers and the city's geographical location subsume it under Northern New Mexican Spanish (Bills and Vigil 2008). Within NNMS, the Spanish traditionally spoken in the city forms part of the Rio Abajo variety which is primarily heard from just north of Albuquerque to down around Socorro (Bills and Vigil 2008).

With the greatest amount of professional, educational, and economic opportunities, Albuquerque, compared to the rest of northern New Mexico has also historically attracted the largest immigrant population from Mexico and Central America (Bills and Vigil 2008; Waltermire 2020). It is no surprise then that Spanish speakers from Albuquerque (and Santa Fe) speak with significantly more mexicanismos (56.8%) in comparison to speakers in other northern New Mexican communities (42.1%) (Waltermire 2020), nor that the majority of the present study's participants report that their parents emigrated to the city from Mexico.

The soundscape of Albuquerque also exemplifies the dialectal mixture between Mexican and New Mexican varieties of Spanish in the city. For instance, Bernalillo informants from the *New Mexico and Colorado Spanish Survey* (Bills and Vigil 2008) frequently produced word-initial "h" as [h] in words like *honda* 'slingshot', but they did not do so with other items like *humo* 'smoke'. The latter pronunciation is more common of Mexican varieties of Spanish. Besides dialect contact, Spanish speakers in the city are often in contact with and/or use English daily. Yet, in an analysis of Spanish-English bilinguals' Spanish and English /ptk/ voice-onset time (VOT) measurements, Balukas and Koops (2014) did not find evidence that bilinguals' Spanish VOT approximates English's long lag VOT. Similar results have been found for prosodic features (Van Buren 2017) and variable morphosyntactic phenomena (Torres Cacoullous and Travis 2018) among speakers in New Mexico. One untested site for phonetic convergence has been the Spanish vowel space, where in other US bilingual varieties, language contact effects have been prominent (Alvord and Rogers 2011; Ronquest 2012).

1.2. Vowel Spaces of Spanish-English Bilinguals

The Spanish vowel space is relatively triangular (Hualde 2014), and it can be described vertically and horizontally. In the vertical dimension, we analyze the height of the tongue when articulating a vowel. In acoustic analyses, height is inversely related to the first formant (F1); so, low vowels, such as [a], have a high F1 and high vowels, such as [i], have a low F1. We can also describe the horizontal dimension of the vowel space, and the second formant (F2) is directly related to tongue advancement, i.e., [i] is a front vowel. As the tongue moves forward, F2 increases (Hualde 2014; Thomas 2011). Children, given their shorter vocal tract, typically have higher formant values than adult speakers of their variety/language (Thomas 2011; Kohn and Farrington 2012). However, these differences are often eliminated via normalization (Menke 2010). Bilingual children also typically develop vowel spaces more similar to vowel spaces of bilingual adults, rather than monolingual adults (Menke 2010). This description and the correlation between vowel height/frontedness and formant values is evident in Table 1.

Table 1 compares mean formant values among three Spanish speaking groups in the United States. Ronquest (2012) and Willis (2005) presented vowel spaces of bilingual adults in Chicago, IL and in El Paso, TX, and Menke (2010) investigated vowel spaces of bilingual children in San Antonio, TX. Overall, the description of vowel spaces presented at the beginning of this section is reflected in the table. However, of note, the adult speakers in Chicago, IL (Ronquest 2012) position high-back vowels in front of mid-back vowels. This intriguing feature (/u/ fronting) is underlined in Table 1. Ronquest (2012) attributed the /u/ fronting to the influence of English, which also has fronted a high-back vowel. In contrast to the findings in Chicago, Menke (2010, 2015) and Willis (2005) did not find this degree of /u/ fronting. Instead, high-back vowels were articulated significantly farther back from speakers’ /o/ realizations. Albuquerque, NM is an attractive community for exploring /u/ fronting. It is a long-standing bilingual community where phonetic convergence with English has been somewhat of an elusive feature (Balukas and Koops 2014; Torres Cacoullos and Ferreira 2000).

Table 1. Mean formant values in three groups of speakers of US varieties of Spanish.

Vowel		F1 (Hz)			F2 (Hz)		
		Ronquest (2012)	Willis (2005)	Menke (2010)	Ronquest (2012)	Willis (2005)	Menke (2010) ¹
/i/	High-front	368	431	475	2207	2434	2868
/e/	Mid-front	499	634	621	1893	2124	2324
/a/	Low-central	688	657	756	1530	1752	1824
/o/	Mid-back	537	642	577	<u>1166</u>	1197	1392
/u/	High-back	421	450	510	<u>1208</u>	1071	1229

Aside from /u/ fronting, /a o/ fronting is of interest in the present study. Willis (2005) also found that both of these vowels were fronted (in comparison to speakers from Spain). The author presented assimilation with English’s /æ/ and a push chain caused by fronting of /o/ as two possible explanations for the fronted /a/. As the present study also examines these vowels and considers factors such as Spanish use and lexical stress, it should be able to assess how these suggestions are borne out in a larger data set in another Southwest population.

To get a clear idea of the predictors of these specific features—/a o u/ fronting, the present study will include lexical stress as an independent variable. Vowels realized in atonic syllables, a prosodically weaker context, are sometimes articulated in a smaller vowel space (Hualde 2014; Moreno-Fernández 2011). However, as this is a much more common sound pattern in English than in Spanish, researchers have considered lexical stress effects as evidence of phonetic convergence between Spanish-English bilinguals’ sound systems (Ronquest 2012). Nevertheless, the lexical stress effect on vowel positioning is not homogenous, as lexical stress effects are found in some communities (Alvord and Rogers 2011; Gildersleeve-Neumann et al. 2009; Ronquest 2012) but not in others (Menke 2010; Willis 2005).

Another internal factor that may explain vocalic variation is word position, as vowels in word final position can display greater variation than vowels in non-word final position (Barajas 2015; Moreno-Fernández 2011). The bulk of Hispanic linguistics research on word position and vocalic realizations has centered on mid-vowel raising in varieties of Spanish spoken in Mexico (see Barajas 2015; Dabkowski 2018 for reviews). However, many studies on bilinguals’ vowel spaces have not focused on potential word position effects, even though it can be another site favoring phonetic convergence (Colantoni et al. 2020). To further expand our range of data and explanatory variables, the present study tests if word position affects their vocalic realizations. The research questions and predictions follow.

1.3. Research Questions and Predictions

RQ1: Does Spanish use predict spectral qualities of bilingual children and adults' Spanish vowels?

P1: *As Spanish use decreases, vowels may be articulated with English-like spectral qualities.*

RQ2: Do lexical stress and word position predict spectral qualities of bilingual children's and adults' Spanish vowels?

P2: *Given that varieties of Spanish spoken in New Mexico typically display little phonetic convergence to English, generalized lexical stress and word position effects are not expected.*

RQ3: Does lexical frequency predict spectral qualities of bilingual children's and adults' Spanish vowels?

P3: *As lexical frequency increases, vowels may be articulated in a condensed vowel space.*

2. Methodology

2.1. Participants

This study details the speech of 23 child Spanish heritage speakers² who are between 3 and 9 years old ($M = 5;04$). All children were born and raised in Albuquerque, New Mexico. The child's narration was selected if Spanish was spoken in the home and if the caregiver reported no language/speech concerns. The children's caregivers reported speaking Mexican ($n = 21$) and New Mexican ($n = 1$) varieties of Spanish. All of the children's parents had emigrated from Mexico except the child with parents from New Mexico.

Six adult Spanish heritage speakers also participated in the study. They have all resided in Albuquerque from, at latest, 7 years of age through their adulthood. They are between 19 and 33 years old ($M = 25$), and they reported hearing Mexican and/or New Mexican varieties of Spanish from their caregivers. Like the children, all adults report that their parents had emigrated from Mexico, except for one participant whose mother grew up in Mexico and whose father was from Northern New Mexico.

2.2. Data Collection

Following Willis (2005), the participants narrated *Frog, Where are You?* (Mayer 1969). During their narration, the researcher did not intervene, and if the participant could not recall a word, the researcher encouraged them to move on without giving any lexical items. The narrations were completed in quiet rooms at a youth development center (children) and on a college campus (adults). The speech data were collected on Zoom H4N and H5N recorders, both with a sample size of 24-bit, a sampling rate of 96 kHz, and a built-in microphone.

2.3. Independent Variables

The present study examines what combination of language-internal, social, and frequency factors predict spectral qualities of vowels produced by Spanish heritage speakers. Age was also assessed in the child data. The language-internal factors are lexical stress (tonic or atonic), word position (final or non-final), and the preceding phonetic segment. The Spanish use and lexical frequency variables are described below.

Spanish use: To assess the relative use of Spanish and English among the children, their caregivers answered seven questions regarding the language(s) used at home. For the full list of questions, see Shin et al. (2019). Five options followed each question, and each option was assigned a score ranging from 0, all English; 1, more English than Spanish; 2, same amount of both languages; 3, more Spanish than English; to 4, all Spanish. One question centers on the ambient language input in the home, three items ask about the input the child receives from the caregiver, other adults in the home, and other children, and

two questions focus on how much the child speaks in Spanish and English to the caregiver and at home. The five questions centering on language input indicate that the children are exposed to a mix of Spanish and English ($M = 2.77$, $SD = 0.76$), as do the two questions that assess language output ($M = 2.66$, $SD = 0.84$). There was a positive and significant correlation between the input and use scores ($r = 0.93$, $p < 0.001$)³. As the children were exposed to more Spanish, they also used more Spanish. To simplify the statistical analyses, only the composite Spanish use measure ($M = 2.74$, $SD = 0.73$) was used.

Spanish use information for the adults was collected with the Bilingual Language Profile (Birdsong et al. 2012). One section of the questionnaire asks, on scales of 0% to 100%, how much Spanish, English, and other languages the participant uses with family, friends, at work, doing math, and when talking to themselves. The adults' language use scores were determined following the protocol provided by the BLP developers. The maximum score on this section is 54.5. Higher scores represent more Spanish use and lower scores represent less Spanish use. The adults use a mix of Spanish and English, but overall, they use slightly more English than Spanish ($M = 21.25$, $SD = 9.37$). Specifically, the adults mostly use Spanish with their families, sometimes when speaking to themselves and with friends, and infrequently at work and when doing math.

Lexical frequency: Counts of each word's token frequency per million words were extracted from CORPES XXI (RAE 2022) which contains over 300 million oral and written forms. To coincide with the varieties of Spanish the speakers have likely frequently used, only the subcorpora of Mexico and United States data were surveyed.

2.4. Vowel Measurements, Normalization, and Statistical Analysis

A total of 2041 Spanish vowels were coded and measured using Praat (Boersma and Weenink 2018): /i/ $n = 255$; /e/ $n = 298$; /a/ $n = 674$; /o/ $n = 646$; /u/ $n = 168$. Any devoiced, aspirated, or creaky articulations, or vowels adjacent to another vowel were excluded. Praat scripts (available here) extracted the F1 and F2 at the midpoint of each token. Afterwards, vowel tokens were plotted to identify and correct erroneous measurements and outliers. Then, all tokens were normalized via the Loboanov method in the Vowel Normalization and Plotting Suite—NORM (Thomas and Kendall 2007).

This method was selected as all vowels in speakers' vowel spaces were included, and because among the six tested normalization methods for child speech by Kohn and Farrington (2012), Lobanov performed the best for preserving sociolinguistic variation and eliminating physiological differences. This method was also selected by Ronquest (2012) and Menke (2010); thus, the results of the present study should be more readily comparable across speech communities in the discussion as well as in future research.

For the statistical analysis, the F1 and F2 dimensions of each phonological vowel were analyzed separately within each age group (child and adult) with linear mixed-effects models from the nlme() package (Pinheiro et al. 2022) in the statistical software RStudio (RStudio Team 2020). In each model, lexical stress, word position, lexical frequency, Spanish use, and age (for the children) were entered as fixed effects. The reference levels for the categorical variables were 'tonic' (lexical stress) and 'non-final' (word position). In the subsets with high vowels, word position yielded low token counts in one level of the independent variable (i.e., 5 word-final /i/ tokens and 250 non-word-final /i/ tokens), so the independent variable was excluded from the models. The research questions also necessitated entering two interactions: Spanish use * lexical stress and Spanish use * word position. In each model, speaker and token were included as random effects. The dependent variables were the normalized F1 (height) or F2 (frontedness) of the vowel.

To find the best-fit model (Levshina 2015), first a baseline model with only the random effects was created. Then, the fixed effects and the interactions were added one by one to the null model. ANOVAs compared the AIC, BIC, log-likelihoods, and p -values of each model. The model with the lowest AIC, BIC, and p -value was considered the best-fit and final model.

Since the Lobanov normalization transforms the raw formant values to z scores, the interpretation of the negative and positive values of regression coefficients depends on the vowel space dimension (F1 or F2). In the height (F1) dimension, negative β values indicate that vowels are realized higher up in the vowel space as a continuous measure increases or in a variable's specific level relative to the reference level, while positive β values indicate that vowels are realized lower down. This correlates with the reversed nature of raw F1 values where low vowels like /a/ have higher F1 values than high vowels like /u/ vowels. Thus, a positive β value for the 'Spanish use' variable in a statistical model on /a/ F1 would indicate vowel lowering as Spanish use increases. In the horizontal (F2) dimension, negative β values indicate that vowels are realized farther back in the vowel space, and positive β values indicate that vowels are realized farther forward. This correlates with the nature of raw F2 values where back vowels like /u/ have lower F2 values than front vowels like /i/. So, a negative β value for the 'Spanish use' variable in a statistical model on /u/ F2 would indicate vowel backing as Spanish use increases.

3. Results

3.1. Adults' Spanish Vowel Spaces

The spectral qualities of adults' vocalic realizations are in line with what has been described in the past literature for Spanish vowel spaces of Spanish-English bilingual adults. First off, their vowel space is not symmetrical. One-way ANOVAs run on the normalized F1 and F2 values showed a main effect of vowel in both the vertical ($F(4,928) = 19.37, p < 0.001$) and horizontal ($F(4,928) = 67.85, p < 0.001$) dimensions. In Figure 1, where lower case "i, e, a, o, u" represent vowels articulated in atonic syllables and upper case "I, E, A, O, U" represent vowels realized in tonic syllables, we see that they articulate /a/ vowels the lowest, followed by /e/, then /o/, then /u/, and they realize /i/ vowels highest up in their vowel space. In the horizontal dimension, the Tukey post hoc test showed that /i e a o/ are all realized in significantly different spaces ($CD = 3.86, p > 0.05$). In addition, /u/ fronting is evident. There was no significant difference between the frontedness of /u/ ($M = 1157$ Hz) and /o/ ($M = 1158$ Hz) ($CD = 3.86, p > 0.05$). The adults only maintain a phonological difference between back vowels in the height dimension: /u/ ($M = 407$ Hz; /o/ ($M = 557$ Hz) ($CD > 4.60, p < 0.01$).

With respect to the fixed effects, it was predicted that as Spanish use decreased, adults would be more likely to articulate Spanish vowels with English-like spectral qualities (P1), that generalized lexical and word position effects (suggesting phonetic convergence) would not be found (P2), and that vowels in more frequent words would be articulated in a condensed vowel space (P3). The results both support and contradict these predictions.

First, P1 is supported by findings for /o a/; the linear mixed-effects models showed that as Spanish use increased, /o/ was articulated farther back in the vowel space ($\beta = -0.03, SE = 0.009, t = -2.87, p = 0.04$). This relationship is demonstrated in Figure 2, where the negative slope of the linear regression line for /o/ (on the right graph) indicates that speakers realize /o/ farther back as Spanish use increases. In a similar fashion, as Spanish use increased, /a/ vowels were articulated farther forward in the vowel space ($\beta = 0.07, SE = 0.01, t = 3.45, p = 0.02$). This relationship is also demonstrated in Figure 2, where the positive slope of the linear regression line for /a/ (on the left graph) indicates that speakers realize /a/ farther forward as Spanish use increases. There was no main effect of Spanish use on /i e u/ realizations. Importantly, this suggests that /u/ fronting may be a generalized vocalic feature of Albuquerque adult bilinguals' vowel spaces.

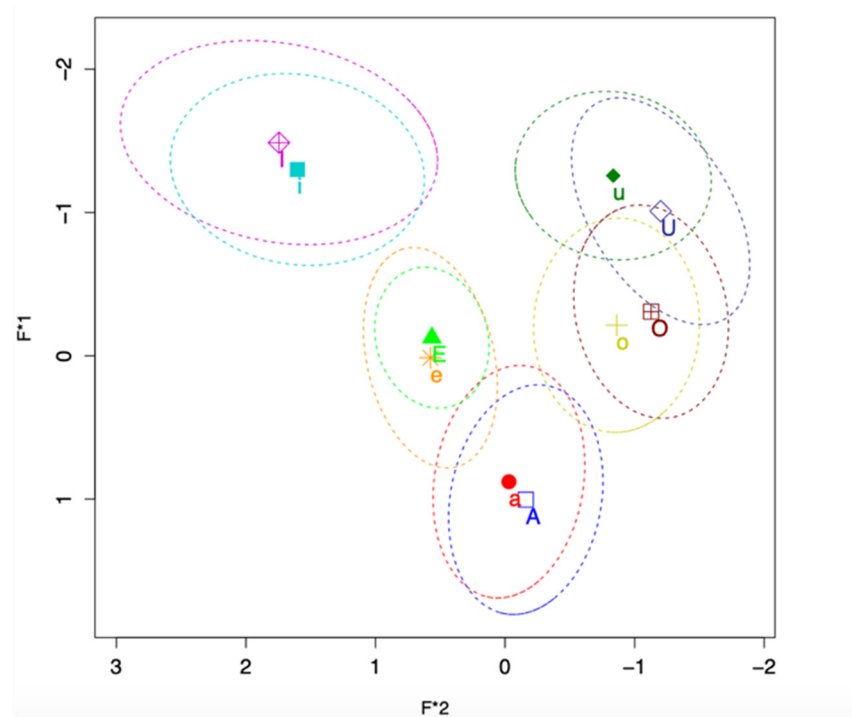


Figure 1. Normalized adult vowel space by lexical stress⁴.

Further support for P1 comes from the significant interaction between lexical stress and Spanish use for the high-front vowel. As Spanish use increased, /i/ in atonic syllables approximated speakers' tonic /i/ realizations in the horizontal dimension ($\beta = 0.07$, $SE = 0.02$, $t = 2.88$, $p = 0.005$). In total, adults' realizations in 3 of 5 phonological vowels are predictable from language use.

Moving on to P2, only for /i/ realizations is there a significant main effect of lexical stress. Contradicting the prediction for lexical stress, /i/ realizations in atonic syllables were significantly lower than those in tonic syllables ($\beta = 0.26$, $SE = 0.11$, $t = 2.37$, $p = 0.02$) regardless of Spanish use. This is evident in Figure 1, where the mean point for "i" realizations and the ellipses enclosing 2 standard deviations from the mean are lower than those for "I" realizations. However, supporting P2, there were no main effects of lexical stress on the four other phonological vowels nor of word position for any vowel. This lack of generalized word position and stress effects overall supports P2.

With respect to P3, bilingual adults' vocalic realizations were not conditioned by lexical frequency. That is, they did not realize vowels in a condensed vowel space as lexical frequency increased. Furthermore, while not part of the predictions, it is important to mention the effects of phonetic context. Articulations of /a/ were also significantly lower in the vowel space after coronal ($\beta = 0.66$, $SE = 0.24$, $t = 2.68$, $p = 0.007$) and velar ($\beta = 0.71$, $SE = 0.27$, $t = 2.64$, $p = 0.008$) segments. The other contexts, labial and palatal, had no significant effect on the vowels' spectral qualities.

In summary, for the adults, /u/ fronting is pervasive in both atonic and tonic syllables. Their realizations of the other high vowel, /i/, demonstrate both generalized and nuanced effects: in atonic syllables, their /i/ realizations are retracted (P2), and as the adults' Spanish use decreases, atonic /i/ realizations retract farther from tonic realizations (P1). General language use effects were also found for /a/ and /o/, since as their Spanish use decreases, /o/ fronts and /a/ retracts (P1).

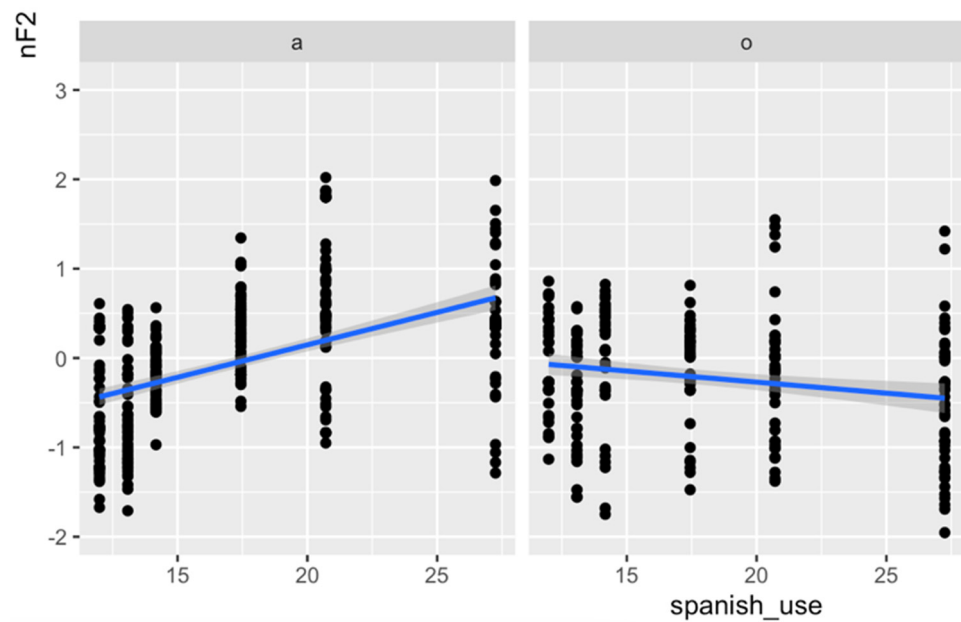


Figure 2. F2 /a o/ realizations by Spanish use.

3.2. Children's Spanish Vowel Spaces

Like the adults' vowel spaces, the children's vowel spaces (Figure 3) are like what has been described in the past literature for Spanish vowel spaces of Spanish-English bilinguals. Their vowel space is also asymmetrical. One-way ANOVAs run on the normalized F1 and F2 values demonstrate a main effect of vowel in both the vertical ($F(4,1103) = 409.37$, $p < 0.001$) and horizontal ($F(4,1103) = 964.4$, $p < 0.001$) dimensions. The Tukey post hoc test showed that all vowel comparisons, including /u/ and /o/, were significantly different ($CD = 4.60$, $p < 0.01$).

Like the predictions made for the adults, it was expected that as Spanish use decreased, children would be more likely to articulate their vowels with English-like spectral qualities (P1), that main effects of lexical and word position would be absent (P2), and that vowels in more frequent words would be articulated in a condensed vowel space (P3). The results both support and contradict these predictions.

First, as Spanish use increased, children's atonic high-back vowels approximated realizations in tonic syllables ($\beta = -0.38$, $SE = 0.13$, $t = -2.21$, $p = 0.006$). Stated differently, as children's Spanish use decreases, they were more likely to front atonic /u/. This is demonstrated by the negative slope of the regression line in Figure 4. Interestingly, in Figure 4, we also see that children with high Spanish use's atonic and tonic /u/ realizations are not differentiated by lexical stress, whereas the children with higher English use articulate atonic /u/ farther forward and tonic /u/ farther back. Aside from this interaction between lexical stress and Spanish use, children's language use did not predict the spectral qualities of their vowels.

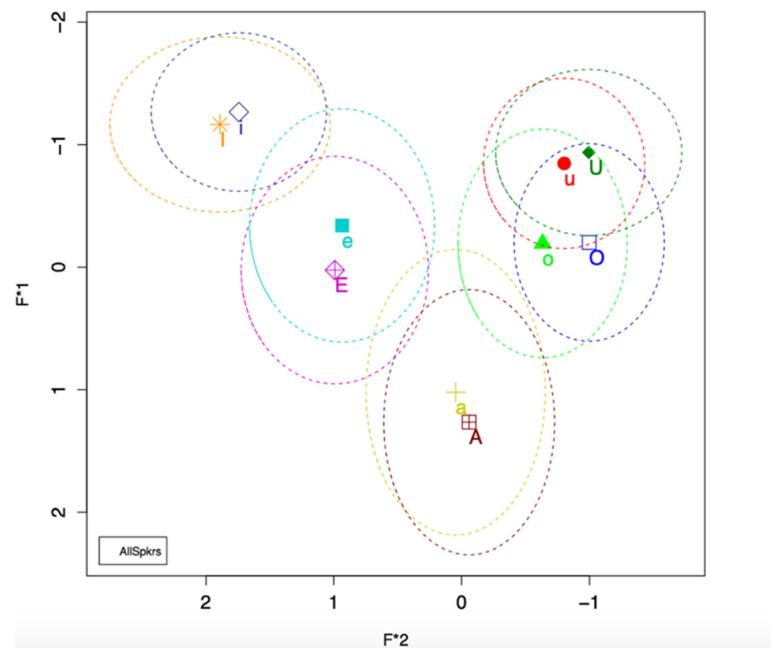


Figure 3. Normalized child vowel space by lexical stress.

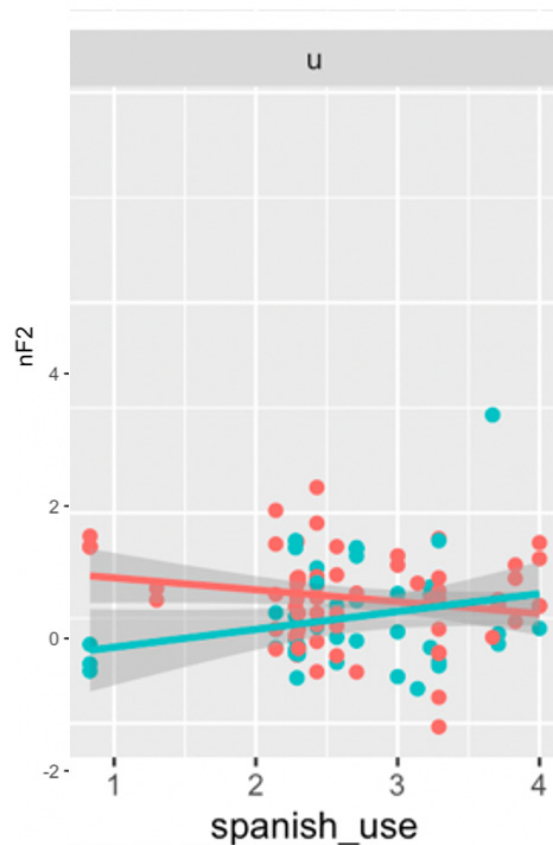


Figure 4. F2 /u/ realizations by Spanish use.

Unlike the absence of a generalized lexical stress effect among the adults, the children’s tonic and atonic vocalic realizations significantly differed more often than not (P2). First, children’s /u/ realizations were significantly farther forward in atonic syllables ($\beta = 0.98$, $SE = 0.38$, $t = 2.56$, $p = 0.02$). This is evident in Figure 3, where the mean point for “u”

realizations and the ellipses enclosing 2 standard deviations from the mean are closer to the middle of the vowel space than those for “U” realizations. In a similar fashion, children’s /o/ realizations were significantly farther forward in atonic syllables ($\beta = 0.25$, $SE = 0.05$, $t = 4.47$, $p < 0.001$). This is also evident in Figure 3 where the mean point for “o” realizations and the ellipses enclosing 2 standard deviations from the mean are closer to the middle of the vowel space than those for “I” realizations. Furthermore, children, regardless of their Spanish use, articulate atonic /a/ vowels higher ($\beta = -0.37$, $SE = 0.11$, $t = -3.48$, $p = 0.007$) and farther forward ($\beta = 0.59$, $SE = 0.24$, $t = 2.42$, $p = 0.01$) in the vowel space. In Figure 3, the mean point for “a” realizations, and the ellipses enclosing 2 standard deviations from the mean are closer to the middle of the vowel space than those for “A” realizations. Lexical stress continues to predict the vertical positioning of mid-front vowels, as /e/ realizations in atonic syllables are positioned higher in the vowel space ($\beta = -0.28$, $SE = 0.11$, $t = -2.19$, $p = 0.03$), as is also evident in Figure 3. However, lexical stress did not significantly predict /i/ positioning. While 4 of 5 phonological vowels are affected by lexical stress, no significant effects were returned for word position. This is essentially the opposite pattern to what was observed in the adults’ speech where only atonic and tonic realizations of 1 of their 5 phonological vowels were significantly different.

With respect to P3, bilingual children’s vocalic realizations were not predictable from lexical frequency in neither the F1 nor F2 dimension. For the phonetic context, after coronal ($\beta = 0.23$, $SE = 0.08$, $t = 2.73$, $p = 0.007$) and velar ($\beta = 0.22$, $SE = 0.10$, $t = 2.21$, $p = 0.03$) phones, /a/ vowels’ F2 was higher. In addition, after coronal ($\beta = 0.38$, $SE = 0.18$, $t = 2.07$, $p = 0.05$) and palatal ($\beta = 0.05$, $SE = 0.19$, $t = 2.61$, $p = 0.009$) phones, /o/ vowels’ F2 was higher. Labial segments never significantly affected the vowels’ spectral characteristics.

Finally, as children aged, they realized /a/ farther forward in the vowel space ($\beta = 0.005$, $SE = 0.02$, $t = 2.48$, $p = 0.02$). However, the one-off age effect may hint at one of Lobanov’s few faults. Kohn and Farrington (2012, p. 2246–47) state that “the normalization techniques are less effective at eliminating differences attributable to physiological differences on the F2 dimension, especially in the lower half of the vowel space . . . [this] impacts normalization techniques that use measures of central tendencies, such as Neary or Lobanov”. At this point, this sole age result with /a/ (the low vowel) is a reflection of the selected methodology.

In summary, children’s vowel spaces display more generalized lexical stress effects than the adults, since, in atonic syllables, children realize /e a o u/ in a significantly smaller vowel space. Moreover, similar to the adults’ realizations with high-front vowels, as children’s Spanish use decreased, atonic high-back /u/ vowels were realized even farther forward.

4. Discussion

The present study has contributed a novel analysis of Spanish heritage speakers’ vocalic realizations by simultaneously examining productions among children and adults in Albuquerque, New Mexico. The main similarities between the findings of the present study and previous research are that the vowel space is not perfectly triangular (Ronquest 2012) and that back vowels are fronted (Ronquest 2012; Menke 2010; Willis 2005). Yet, in contrast to Menke’s (2010) findings for other bilingual children in the Southwest, lexical stress effects are evident among child heritage speakers in Albuquerque, New Mexico. In what follows, we will first review the results for the frequency variable included in this study, then discuss findings related to Spanish use, lexical stress, and /u/ fronting. The discussion will lead to suggestions about incorporating demographic measures into models of phonetic acquisition, variation, and change.

Three demographic measures—count, density, and language loyalty—will serve to describe community level Spanish use in the area. Following Jenkins’ (2009) definitions, ‘count’ is the raw number of Spanish speakers over the age of 5 in a given county, ‘density’ measures the percentage of the total county population ages 5 and older that speaks Spanish at home, and ‘language loyalty’ is the percentage of individuals who identify as

Hispanic/Latinx and report speaking Spanish at home. To extract this measure, the total count of Hispanic/Latinx individuals who speak Spanish at home was divided by the total number of Hispanic/Latinx individuals in the county⁵. Together, these measurements give us an idea of the community level presence of Spanish as well as its maintenance. A fourth measure—self-reported English proficiency—was also used. This is the percentage of Hispanic/Latinx Spanish speakers over the age of 5 who report speaking Spanish in the home who also report speaking English “very well”. The label “very well” is certainly subjective. Furthermore, given that the cut off point for “very well” was assessed to be accurate with standardized English proficiency materials, the measure likely represents experience with English in educational settings more than home language use (see [Leeman 2015](#) for additional commentary). However, that is exactly why this measure is useful to the present study. Scholars have cited the onset of schooling, where the language of instruction is usually English, as the time that the heritage language starts to decrease in use. Therefore, knowing the percentage of the Spanish speaking population that reports proficiency in English, along with information about Spanish language maintenance, can better inform us of the sociolinguistic environment of our speakers.

First off, one of the study’s novel contributions to the body of research on Spanish heritage speakers’ vocalic productions was the inclusion of a lexical frequency measure. Following previous research ([Alba 2008](#); [File-Muriel 2009](#)) and theoretical approaches to frequency effects ([Bybee 2001](#)), it was predicted that as lexical frequency increased, vowels would be realized in a more condensed vowel space (P3). However, this measure did not predict the spectral qualities of the speakers’ vocalic realizations. Here, one thing to keep in mind is that frequency effects are not of the ‘one size fits all’ type. By this, I mean that frequency, and its effects, can be measured in a multitude of ways and explored with both discrete and continuous variables. Often, one frequency variable is also more explanatory than others. A perfect example comes from [Alba’s \(2008\)](#) work on hiatus resolution among New Mexican Spanish speakers where the frequency ratio of two-word sequences was a better predictor of resolutions than a word’s token frequency. Another example comes from [Torres Cacoullos and Ferreira’s \(2000\)](#) study on [v] retention by New Mexican Spanish speakers where [v] retention was predicted by a discrete frequency measure that was based on token frequency counts. These two examples suggest that we should continue to consider frequency effects in Spanish-English bilinguals’ Spanish vowel spaces even if the specific lexical frequency variable selected in the present study was not explanatory.

Aside from looking at lexical frequency, the present study considered language use effects. For both children and adults, it was predicted that as Spanish use decreased, English-like phonetic features would be more common. Language use effects of Spanish use were found for adults’ /i a o/ realizations and for children’s /u/ articulations. As their Spanish use increased, atonic realizations of high vowels were articulated in a significantly smaller space compared to their tonic counter parts. In both cases the pattern evidences phonetic convergence since laxing of unstressed vowels is a more typical English-like than Spanish-like pattern. The study also found that adults realized /o/ farther forward and /a/ farther back as Spanish use decreased. These results contrast [Willis’ \(2005\)](#) hypotheses that /a/ fronting could be influenced by /æ/ or by a push-chain shift starting with their fronted /o/. Here, the /a/ retraction could be a result of the adult speakers’ maintenance of a phonological distinction with /æ/, which, different from a monolingual Spanish speaker’s sound patterns, is more frequent in a Spanish-English bilinguals’ linguistic repertoire, especially among those with high English use. In addition, the fact that /o/ vowels were realized farther forward as Spanish use decreased suggests that the patterning with both vowels are independent processes. In both cases, the influence of frequently using English affects vocalic positioning, but it is not necessarily the case that one development induces the other.

While both children’s and adults’ vocalic realizations see English influence, the major difference between the bilingual adults’ and children’s vocalic realizations is found in the results for lexical stress. While 1 of 5 of the adults’ phonological vowels was susceptible

to spectral reduction in atonic syllables, 4 of 5 of children’s vowels were realized in a significantly smaller space in atonic syllables. The present study predicted that generalized lexical stress effects would not be found in these bilingual populations as their community members’ speech patterns, in other studies, have displayed little evidence of phonetic convergence with English (Balukas and Koops 2014; Torres Cacoulllos and Ferreira 2000; Torres Cacoulllos and Travis 2018; Van Buren 2017; Vigil 2018). Clearly, P2 was only supported in the adult data. The more nuanced effect among the adults and the generalized lexical stress effect among the children can be framed within the shifting sociolinguistic environment in Albuquerque.

Table 2⁶ provides the four demographic measurements with data from the 2000 US Decennial Census and the 2019 American Community Survey (5-year estimates) (US Census Bureau 2019a, 2019b). Here we see that the number of Spanish speakers in the county has increased, but that the density of Spanish speakers has remained stable. The largest change in the last ~20 years has been in language loyalty, from 59.1% in 2000 to 45.1% in 2019. The decline in loyalty is inverse to the percentage of Hispanic/Latinx Spanish speakers who report speaking English “very well”. The comparison between these data points suggests that while the representation of Spanish speakers in the community is stable, Spanish language maintenance in the Hispanic/Latinx community has somewhat decreased in the past two decades.

Table 2. Linguistic-demographic measures from the US census.

Spanish Language Data—Bernalillo County, 2000				Spanish Language Data—Bernalillo County, 2019			
Count	Density	Loyalty	Self-Reported English Prof.	Count	Density	Loyalty	Self-Reported English Prof.
128,162	23.0%	59.0%	69.3%	149,370	23.4%	45.1%	73.0%

This change in the last two decades helps to explain why lexical stress effects are more generalized among child heritage speakers than adults in the present study, and as we will see below, between child populations. Specifically, in Albuquerque, the younger speakers are acquiring Spanish in a city where Spanish has been in increasingly closer contact with English. While both named languages have coexisted in the region for several hundred years, English is now the more commonly used language in Hispanics’ homes, and English continues to be the dominant language of instruction. The results of the present study are explicable with these demographic trends since phonetic convergence is more likely with geographical proximity, consistent contact, and linguistic borrowings (Aikhenvald 2002). This spectral reduction in atonic vowels could be considered one linguistic result of the consistent contact and increased geographical proximity since the phonetic patterns of two named languages, ‘Spanish’ and ‘English’, used by an individual, have become more similar. The lack of word position effects found in the present study speaks to the fact that certain phonetic environments are more favorable or plausible sites for these phenomena, and that, at the very least, word position effects vary by community (Colantoni et al. 2020). While the children all similarly realize vowels in atonic syllables different from those in tonic syllables, suggesting an overall change in the degree of phonetic convergence between Spanish-like and English-like sound patterns in Albuquerque, their /u/ fronting is more idiosyncratic and connected closely with their individual language use.

At the beginning, it was predicted that /u/ fronting would not be a generalized characteristic among Spanish-English bilingual children and adults in Albuquerque, but that with decreased Spanish use, /u/ fronting would be more likely. As a group, the adults actually realized /u/ vowels in the same horizontal space as their tonic and atonic /o/ realizations. Furthermore, their /u/ fronting was not a product of syllable stress, current Spanish use, nor of an interaction between these variables. These results suggest that /u/ fronting is a general feature of their vowel spaces. However, their degree of /u/ fronting is different from what has been found in past research.

Much like we can find among adult speakers, children in different bilingual communities front /u/ to different degrees. The children in Albuquerque also make a smaller phonological distinction between back vowels than children in San Antonio (Menke 2010, 2015). This is the same comparison that can be made between adult speakers in Chicago (highest degree of fronting), Albuquerque, and El Paso (lowest degree of fronting). Since /u/ fronting is typically attributed to a bilingual’s greater English use (Ronquest 2012), it could also be the case that as Spanish use and the language’s community presence increases, /u/ fronting is less pervasive in children’s speech.

Table 3 reports the raw F2 Hertz difference between tonic /o u/ values and three census data points for children in Bexar county (San Antonio—Menke 2010) and Bernalillo county (Albuquerque—present study). The Albuquerque children make a much smaller backness distinction between /o/ and /u/ than the children in San Antonio. As predicted, it is the case that a larger difference between back vowels is attested in the community with a greater count and density of Spanish speakers, and in the community where language loyalty is higher. The relationship between /u/ fronting in adult populations and community language use is also borne out for two of the three demographic measurements between speakers in Cook county (Chicago, IL—Ronquest 2012), El Paso county (El Paso, TX—Willis 2005), and Bernalillo county (Albuquerque—present study). Table 4 shows that loyalty is lowest in Bernalillo, higher in Cook, and highest in El Paso county where /u/ fronting is least visible. Density in Bernalillo and Cook are also much lower than the figure for El Paso. Importantly, this demonstrates that the phonetic characteristics found in the present study fall along a continuum of phonetic features that can coincide with each presented community’s unique sociolinguistic environment.

Table 3. Census data and /u/ fronting in children by county (city).

Measure	Bernalillo (Children) (Albuquerque)	Bexar County (San Antonio)
/o/-/u/ difference	38 Hz	100 Hz
Density	23.37%	34.92%
Loyalty	45.10%	57.53%
Count	149,370	651,205

Table 4. Census data and /u/ fronting in adults by county (city).

Measure	Bernalillo (Adults) (Albuquerque)	Cook County (Chicago)	El Paso County (El Paso)
/o/-/u/ difference	1 Hz	−42 Hz	126 Hz
Density	23.37%	20.83%	67.67%
Loyalty	45.10%	80.39%	94.33%
Count	149,370	1,008,076	527,755

Now, while there is a general pattern between /u/ fronting and community language use, the present study found that as children’s English use increased, atonic /u/ farther fronted (Figure 4). The relationship between decreasing use and increasing distance between tonic and atonic realizations can be considered further evidence that a bilingual’s ‘named language’ sound patterns can approximate each other. This finding, in conjunction with the generalized lexical stress effect among the children, demonstrates how even when a group of speakers are placed on a continuum with other speaker groups, the same continuum applies at the individual level. Specifically, the macro language use/maintenance measures are useful to see intercommunity differences, but the local language measures (the language background questionnaires) better demonstrate intracommunity variation.

5. Conclusions

This study contributed the first acoustic analysis of child and adult Spanish heritage speaker's Spanish vowel spaces in New Mexico, but by no means should it be the last. The comparison between vocalic patterns and demographic information demonstrated that the degree of phonetic convergence in heritage speakers' vowel spaces varies synchronically with Spanish language maintenance and that it changes over time with community language shift. This was especially the case with the discrepancy in lexical stress effects between the age groups. Furthermore, within their age group, language use predicted the spectral qualities of vowels. Therefore, in addition to including language use in models of phonetic and phonological acquisition, we should incorporate larger community language practices. Doing so would situate language development among both monolingual, bilingual, and multilingual children in their unique community, as well as contribute to our greater understanding of heritage language acquisition.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of the University of New Mexico (protocol code 12314 and 01/06/2021).

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Data Availability Statement: No data in this study are publicly available at the time of publication.

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Notes

- ¹ These values reflect the vowel space of the first graders in her study, which are closest in age to the children in the present study.
- ² The author thanks Drs. Naomi Shin and Barbara Rodriguez for use of their data (narration audio and background questionnaires).
- ³ Pearson's product-moment coefficient r .
- ⁴ Reading Lobanov plots: 0 represents a central x and y axes. Values closest to 0 are most centralized in F1 and F2. F1 is reported on the y axis. Values less than 0 are higher up in the vowel space, and values greater than 0 are lower in the vowel space. The same relationships apply to F2 on the x axis. Values less than 0 are farther back in the vowel space, and values greater than 0 are farther forward.
- ⁵ Effectively, these are only a handful of measurements that can demonstrate macro-language use and maintenance. No measure will tell us everything. I have selected the most widely used measures for the present study. See Mora et al. (2005) for other types of language use/maintenance measures.
- ⁶ I am grateful to Devin Jenkins for sharing the demographic data presented in Tables 2–4 with me. Unless otherwise noted, the data come from the US Census US Census Bureau (2019a, 2019b).

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