Abstract:

Velar stops, and velar fricatives may become palatalized before front vowels in the dialects of Chile and Mexico, and palatalized before /a/, which has been fronted, in Castilian Spanish. These sound changes are fairly common in the world's languages, but research proves that it is not certain under which circumstances these sound changes take place and to what extent in each dialect. Acoustic data is provided in support of the hypothesis that Chilean Spanish palatalizes in more environments than the other two dialects, although Castilian may palatalize in different environments than the other two dialects due to a historical shift in the Gallo-romance languages (before front vowels and /a/).

Introduction

The entire field of Spanish linguistics is defined by the last 100 years of scholarship (Lipski, 1998). The Chilean dialect of Spanish is one of many less-documented dialects within the field of Spanish linguistics. The great diversity that exists within dialects of South America has prompted numerous researchers to investigate and explain such enormous dialectical variation [Lipski, 1998]. In the search for acoustic detail surrounding this dialect, many acoustical features have been investigated, although there exist great scarcities within certain dialectical areas of study. Lipski states for example:

> There are few monographic works describing national variants of Spanish (Oroz 1966 and Lenz 1940 for Chile, Vidal de Battini 1964 for Argentina, Navarro Tomras 1948 for Puerto Rico, Henriquez Urefia 1940 and Jimenez Sabater 1975 for the Dominican Republic are noteworthy exceptions); found instead are monographs describing regional varieties, or those confined to a particular dimension, usually the lexicon or aspects of

pronunciation. Historical accounts of the development of specific dialects are scarcer still: Alvarez Nazario (1991) for Puerto Rico and Fontanella de Weinberg (1987) for Buenos Aires are superb treatises which stand virtually alone in historical dialectology. [Lipski, 1998, p. 252]

The work presented here explores the acoustical qualities for a sound change that has occurred over time in many of the world's languages: velar palatalization in Chilean, Mexican, and Castilian dialects of Spanish. The main focus will be on voiceless velar palatalization before the front vowel environment.

Traditionally, the sound change from [k] to [tʃ] (palatalization) is considered to be a gradual articulatory change (Guion, 1998, p. 18). Although a very common sound change, it is still not clearly understood under which articulatory circumstances such velar softening occurs:

> One view proposes that a fronted [k] can develop a fricative release which precipitates a shift in articulation to a more anterior position[Grammont, 1933, p. 214; Hock, 1991, pp.73-77]. Another view proposes that a fronted velar acquires a palatal offglide and then is shifted to a coronal place of articulation due to the narrow shape of the vocal tract [Anttila, 1989, pp.72-73]. [Guion pp. 19]

There is still debate surrounding whether palatalization is a purely articulatorily motivated change [Guion, 1998, p. 19]. In this study specific acoustic features will be measured to determine the extent of palatalization of velars /k/ and /x/ in reference to alveolopalatal affricate /tʃ/.

There is infinite variability within speech [Ohala, 1993, p. 239] not only when segments of words are spoken by different speakers, but cross-dialectically. The further investigation of these dialects relevant to palatalization will give us insight into such variation, in which environments such variation occurs, and to what extent between dialects.

The palatalization of voiceless velar stops is characteristically relevant to the respective vowel environment in which it is found. The length of aspiration within the consonant is affected by the following vowel. Before a high vowel there will occur longer frication and aspiration [Guion, 1998]. Velar softening is implemented before front vocalic segments consistent with the well-known fact that velar stops are articulated at a more fronted or anterior location in the contextual condition than before low and back rounded vowels and /w/ [Recasens, Espinosa, 2009, p. 189]. In order to measure such acoustic variance before front vowels, all three consonantal environments' following vowel formant measurements were gathered. The height of the second formant is always associated with the position of the tongue, and it is assumed that when the tongue moves forward and approaches the palate, the frequency of the second formant rises [D'Introno, Del Teso, Weston, 1995, p. 91]. Acoustic similarity between both front /k/ and /tʃ/ is enhanced by the F2 vowel transition endpoints [Recasens, Espinosa, 2009, p. 190].

In addition to second vowel formant measurements, spectral moments of the consonant segments were also analyzed. The argument for preferring the use of spectral moments to measure such sound change is based in the fact that spectral moments better capture the important spectral shape features in a manner that varies less across individual utterances, across speakers, and cross-dialectically [Bunnel, Polikaff, Mcnicholas, 2004, p.2].

Voiceless velar palatalization can also be attributed to a historical sound change within the Romance language family. This first palatalization wave caused /k/ to become /tʃ/ before front vowels and /j/ in all languages except for Sardinian, which suggests this process can be traced back to Late Latin and must have been completed by the 5th century A.D.

[Recasens, Espinosa, 2009, pp. 189]. This velar softening, however, occurred twice in two different sets of conditions: 1. only before front vocalic segments in Late Latin and in nearly all Romance languages and 2. Before other vowels and word finally in a subset of Romance languages and dialects a few centuries later. [Recasens, Espinosa, 2009, pp. 193].

A theory of acoustic equivalence was proposed between the front velar stop burst and /tʃ/ frication noise found in several languages that share a spectral peak frequency at about 2500-3500 Hz Ohala and Colleagues argue [Recasens, Espinosa, 2009, pp. 190]. In measuring the spectral moments of the consonant segments /ka/, /ke/, /ki/, /ku/, /xa/, /xe/, /xi/, /xu/, /tʃa/, /tʃe/, /tʃi/, /tʃu/ this similarity can be measured, along with F2 of both previous to token and following token vowel giving us information surrounding the quality of the vowel and in turn the placement of the consonant across dialects.

Methods

Speakers

19 native Spanish speakers participated in this study. 8 speakers from Santiago, Chile, 7 speakers from Northern Mexico (Sonora), 1 speaker from Mexico City, and 3 speakers of Castilian Spanish from Spain. Of the Chilean speakers, 3 were male and 5 female. Of the Mexican speakers, 3 were female and 5 male. The Castilian Spanish speakers numbered 2 male and 1 female. The speakers ranged in age from 17 to 55 and had no known hearing loss or speech impairment.

Materials

A list of 83 phrases was given to each participant to read aloud. 25 of the 83 phrases originally presented were distracter phrases to allow for comfortable variation for participants. The participants did not know the purpose of the study. Each phrase was identical in structure differing only in the respective segments of interest (vowel consonant VC and consonant vowel CV transitions and measurements). The consonants of interest were /k/,/x/, and / tʃ/ respectively and each appeared word-initially within the token. Each target consonant was to be followed by one of four vowels of Spanish studied in this experiment (/a/, /e/, /i/, /u/). The phrase structure was as follows: controlled phrase introduction (“digo la”) CV target word, controlled phrase closure “porque sí” (digo la#CV… porque si). This phrase structure was consistent for each segment, for every speaker.

A full list of words can be found in Appendix 1.

Word alterations

The words were tri-syllabic except for in specific cases where the lexicon did not provide sufficient items. The original target number for each CV combination word output was 10. In environments with an especially low yield of words, conditions were altered: In the environment of velar voiceless fricative /x/ before mid front unrounded vowel /e/(two syllable word “gestión”, and four syllable word “genética” added). In the environment of voiceless postalveolar affricate /tʃ/ before high front unrounded vowel /i/ one word (two-syllable “chicha” was added). There were 912 tokens total and 48 tokens per speaker.

Throughout the analysis, some CV sequences were found to be problematic for retrieving any following vowel measurements. There were instances within the data for

Mexican speakers within which the word /tʃintʃija/ was pronounced with the word initial token /tʃ/ followed not by /i/ but rather by a syllabic nasal. This made it an impossibility to measure the following vowel formants in question. Other curiosities within the data included following vowel deletion in word initial /k/ or /tʃ/ followed by token vowel and another obstruent. /tʃitara/ for example, would end up with no vowel between the two consonants /tʃ/ and /t/. In cases where such tokens were excluded from the measurement, the token was not measured.

Procedure

The 912 tokens were recorded directly to a hard drive into a head-mounted microphone using the program Praat, and digitized to at 44100hz. Each speaker was recorded in a specifically isolated and quiet place within homes or office spaces. Each speaker was advised to read through the list first to test comprehension and preparedness. Multiple repetitions were not recorded, but speakers were instructed that a repetition of an item was a possibility if they felt they mispronounced something. In such cases only the last or correct token was used.

Measurement methods

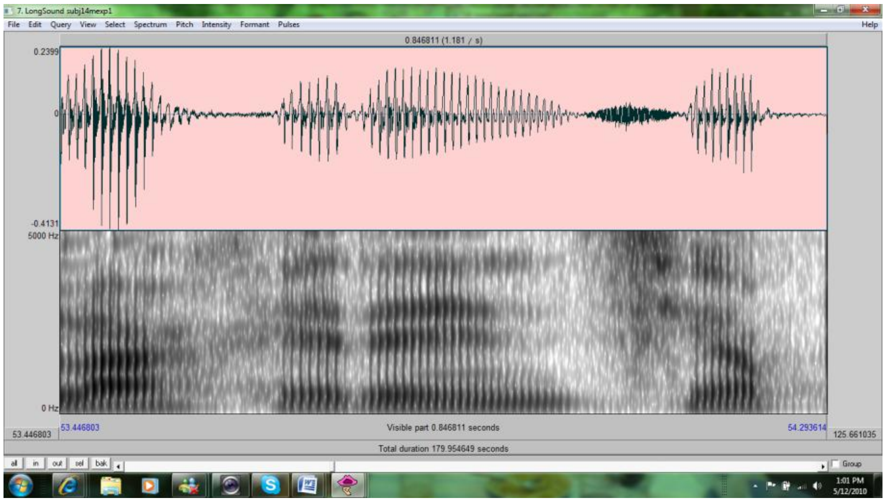
5 measurements were made per token. The previous vowel, the consonant characteristics, and the following vowel were analyzed. The F2 of the previous vowel was identified at two points: both at midpoint (point of regularity within F2 frequency trend) and offset (onset of frication or F2 non-clarity) from spectral displays. The consonants were measured according to the following: Stops (/k/) after the burst until onset of the following vowel (until F2 frequency was apparent), fricatives (/x/) from beginning to end of frication noise, affricates (/tʃ/) from offset of the burst until onset of the following vowel (when F2

frequency was apparent, and encompassing all frication noise) from spectral displays. The Following vowel was measured at two time points: both the onset (where regular wave forms and F2 frequency showed) and midpoint for the second formant (a point of regularity within F2 frequency trend) from spectral displays.

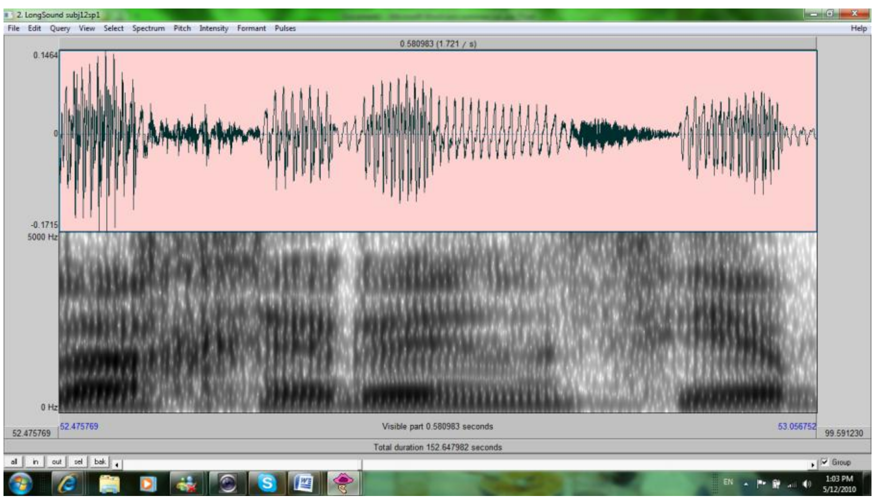
All four spectral moments (1. Center of gravity, 2. Standard deviation, 3. Skewness, 4. Kurtosis) were measured at two time points for each consonant: for /x/ and /tʃ/ a 40ms window centered on the middle of the frication noise, and for /k/ a 40ms window from the onset of the burst.

Results

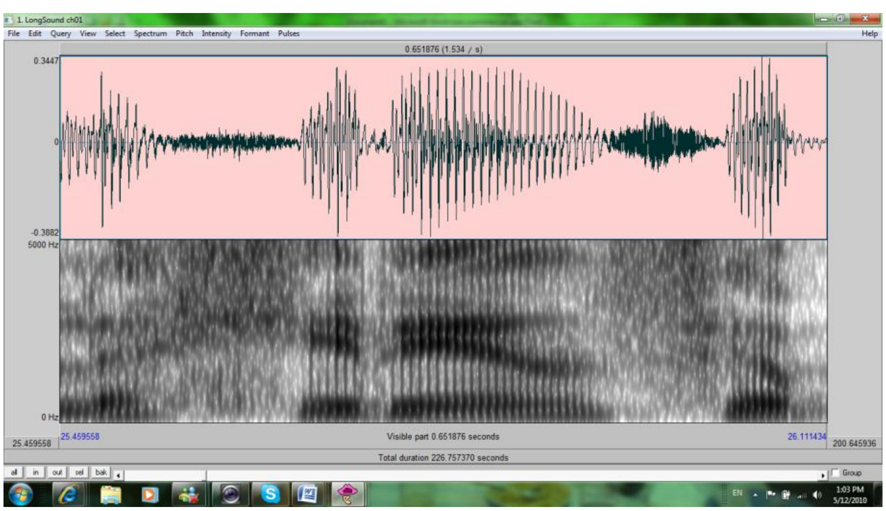
Figure 1



a.



b.



c.

Figure 2

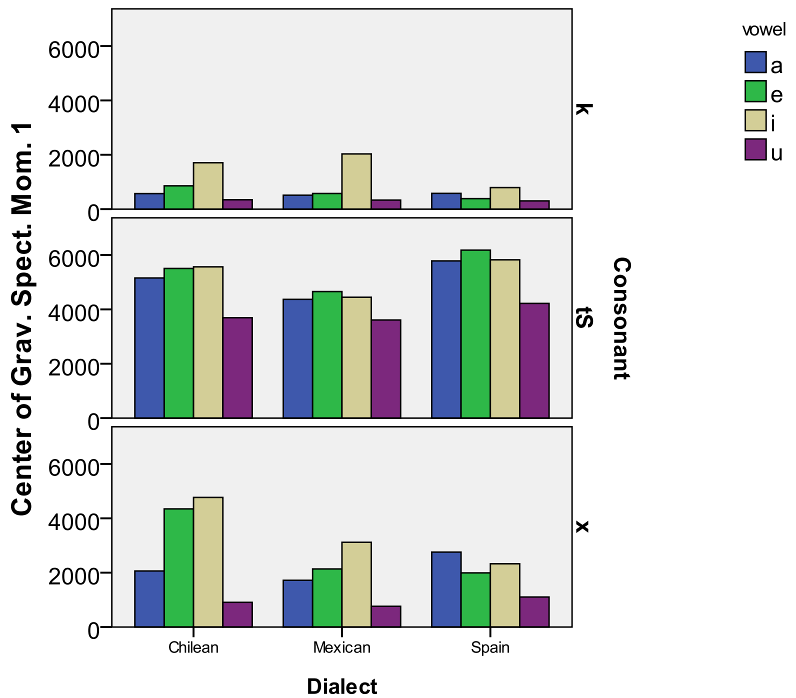


Figure 3

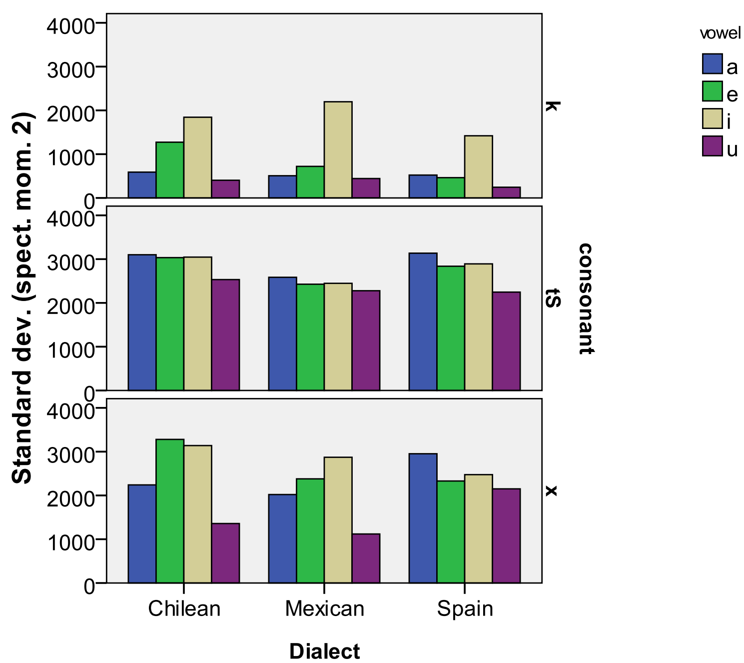


Figure 4

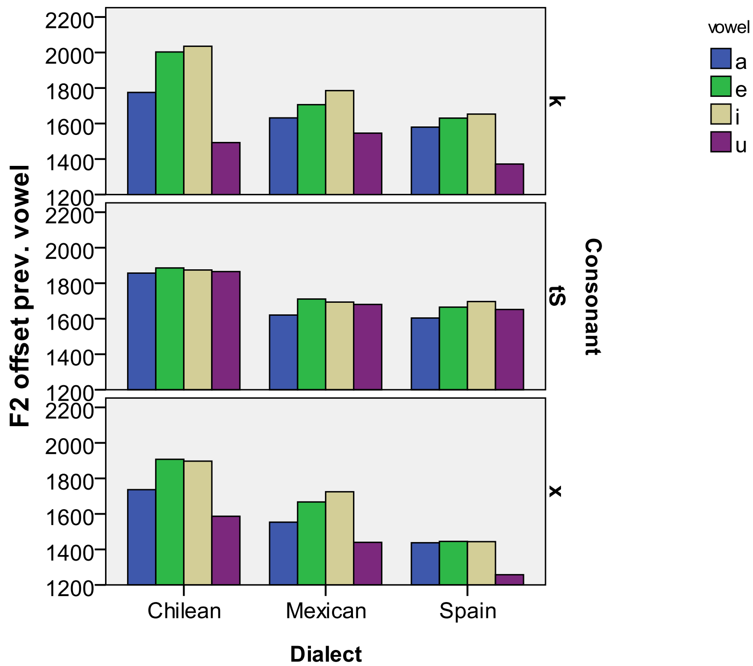
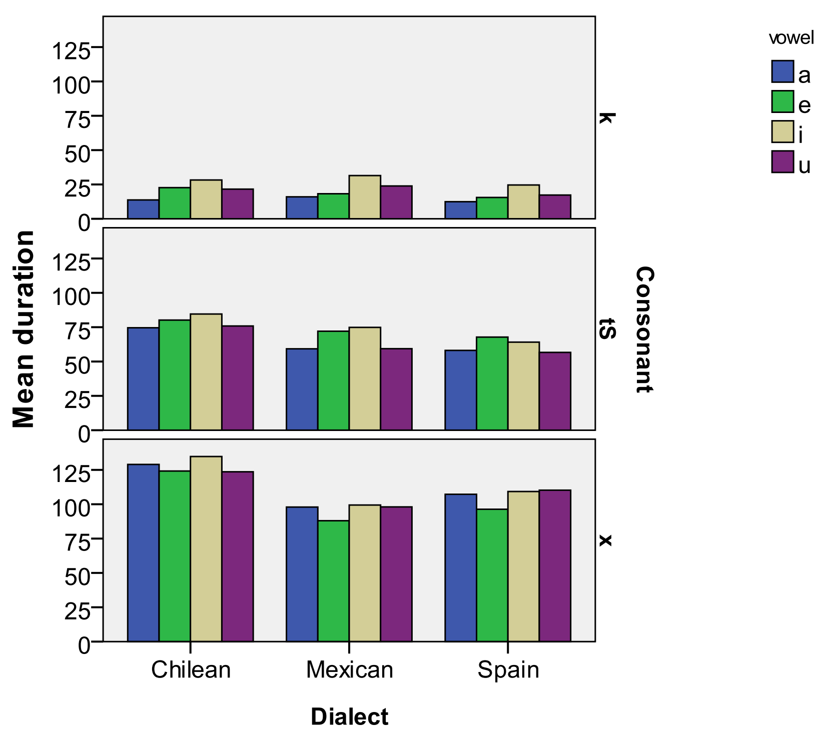


Figure 5



All measurements were averaged over the items within a condition before analysis.

The time points for the spectral moments analyzed are found relatively far from the vowel in the middle of the consonant . This time point was chosen to indicate whether the consonant itself was fronted without including part of the vowel in the respective window. F2 and offset of PV is also analyzed as a different way to examine degree of fronting while keeping that vowel constant, thus yielding more interpretable data interdialectically.

A spectral representation of /x/ before /e/ in all three dialects (see figure 1 a. Mexican, b. Castilian, and c. Chilean) is shown above.

Spectral moment 1 during first time point (see figure 2)

The data for center of gravity (first spectral moment) for /x/ and /tS/ measured a 40ms window centered on the middle of the frication noise. For /k/ a 40ms window was measured from the onset of the burst, and analyzed using a three factor mixed design ANOVA, with the factors consonant (k, x, tS), following vowel (I, e, a, u), and dialect (Chilean, Mexican, Castilian). The dialect factor was between subjects and the other two factors were within subjects. The main effects of consonant and following vowel were significant (consonant: $F(2,32)=299.98$, $p<.001$; vowel: $F(3,48)=52.92$, $p<.001$). The main effect of dialect was not significant ($F(2,16)=1.93$, $p>.05$). All interactions were significant (consonant by dialect: $F(4,32)=5.63$, $p<.005$; Vowel by dialect: $F(6,48)=5.21$, $p<.001$; consonant by vowel: $F(6,96)=13.23$, $p<.001$; three way interaction: $F(12,96)=5.33$, $p<.001$).

Because of the significant three-way interaction, the two-factor ANOVA with following vowel and dialect was tested for each consonant separately. For /k/, the main effect of following vowel was significant with /k/ before /i/ having higher center of gravity than /k/ before other vowels ($F(3,48)=10.17$, $p<.001$). However, the main effect of dialect was not significant ($F(2,16)=.92$, $p>.05$). The interaction was also not significant ($F(6,48)=1.10$, $p>.05$). Thus the center of gravity was higher before /i/ than before other vowels for /k/, indicating palatalization before /i/, but this pattern did not differ by dialect, and therefore will not be pursued further.

The main effect of following vowel was significant for /tS/ ($F(3,48)=71.50$, $p<.001$), but the main effect of dialect was not significant ($F(2,16)=2.45$, $p>.05$). Their interaction was, however, significant ($F(6,48)=3.99$,$p<.005$). /tS/ appears to have higher center of gravity before all vowels other than /u/, but this effect is somewhat smaller for the Mexican dialect than for the other two dialects analyzed. Because palatalization of /tS/ was not the primary question, this interaction was not pursued further.

Both main effects and the interaction were significant for /x/ (vowel: $F(3,48)=47.64$, $p<.001$; dialect: $F(2,16)=4.31$, $p<.04$; Interaction: $F(6,48)=10.37$, $p<.001$). Because of the significant two-way interaction of vowel by dialect, the simple effect of following vowel was tested for each dialect separately for just /x/. This was done to determine which vowels cause palatalization in the consonant. All three dialects showed a significant simple effect of following vowel on the center of gravity of /x/ (Chilean: $F(3,21)=69.71$, $p<.001$; Mexican: $F(3,21)=18.49$, $p<.001$; Castilian: $F(3,6)=11.88$, $p<.01$). The interaction reflects the fact that for

Chilean and Mexican speakers, /x/ before /i/ has the highest center of gravity, with /e/ following, and /a/ following that, and /u/ the lowest. For Castilian however, /x/ before /a/ has the highest center of gravity.

To determine which consonants are significantly palatalized relative to which others, a series of pairwise comparisons was performed within each dialect. For Chilean, /x/ before /i/ and /e/ both had a significantly higher center of gravity than /x/ before /a/ (/i/: $F(1,7)=54.26$, $p<.001$; /e/: $F(1,7)=114.06$, $p<.001$). /x/ before /i/ and /e/ had equally high center of gravity and did not differ from one another ($F(1,7)=3.72$, $p>.05$). This indicates that for the Chilean dialect, /x/ is fronted before both /i/ and /e/.

For the Mexican dialect, /x/ before /i/ had a significantly higher center of gravity than /x/ before /a/ ($F(1,7)=12.55$, $p<.01$), however, /x/ before /e/ did not ($F(1,7)=2.88$, $p>.05$). /x/ before /i/ and /e/ were significantly different from each other ($F(1,7)=12.08$, $p<.02$). This indicates that for the Mexican dialect of Spanish /x/ before /i/ is fronted, while /x/ before /e/ is not.

For Castilian, results appear to indicate fronting before /a/ rather than the other vowels studied (Figure 2). There are only three speakers in the study for this dialect, so statistical power was limited, however, the statistical results indicate several differences. Unlike the other dialects, neither /x/ before /i/ nor /x/ before /e/ differs from /x/ before /a/ (/i/: $F(1,2)=.97$, $p>.05$; /e/: $F(1,2)=3.86$, $p>.05$). However /x/ before /a/ and /i/ both showed significantly higher center of gravity relative to /x/ before /u/(/i/: $F(1,2)=25.81$, $p<.04$; /a/: $F(1,2)=55.56$, $p<.02$). /x/ before /e/ was not significantly different than /x/ before /u/, although it showed a non-significant trend in the same direction (F(1,2)=18.13, p=.051). This indicates that /x/ is somewhat fronted before both /i/ and /a/ and perhaps slightly so before /e/.

Spectral moment number 2 during first time point (see figure 3)

The data for Standard deviation (second spectral moment) measured at (time window) was analyzed using the same three factor mixed design ANOVA as for Center of Gravity above, with the factors consonant (k, x, tS), following vowel (i, e, a, u), and dialect (Chilean, Mexican, Castilian). The main effects of consonant and following vowel were significant (consonant: F(2,32)=299.98, p<.001; Vowel: F(3,48)=52.92, p<.001). The main effect of dialect was not significant (F(2,16)=1.93, p>.05). The interaction of consonant by dialect was non-significant (consonant by dialect: F(4,32)=1.70, p>.05). All other interactions were significant (Vowel by dialect: F(6,48)=4.92, p<.002; consonant by vowel: F(6,96)=14.09, p<.001; three-way interaction: F(12,96)=2.53, p<.007).

Because of the significant three-way interaction, the two-factor ANOVA with following vowel and dialect was tested for each consonant separately, as it was for center of gravity above. For /k/, the main effect of following vowel was significant with /k/ before /i/ having a higher standard deviation than /k/ before other vowels (F(3,48)=33.03, p<.001). However, the main effect of dialect was not significant (F(2,16)=1.75, p>.05). The interaction was also not significant (F(6,48)=1.92, p>.05). Thus the standard deviation was higher before /i/ than before other vowels for /k/, but this pattern did not differ by dialect, and therefore will not be pursued further.

The main effect of following vowel was significant for /tS/ (F(3,48)=13.32, p<.001), but the main effect of dialect as well as the interaction between vowel and dialect was non-significant (dialect: F(2,16)=2.88, p>.05; Interaction: F(2,16)=1.59, p>.05). /tS/ appears to have higher standard deviation before all vowels other than /u/. This effect is somewhat smaller for the Mexican dialect than for the other two dialects analyzed, but this difference in size of effect is not significant, as indicated by the non-significant interaction.). Because palatalization of /tS/ was not the primary question, this interaction was not pursued further.

The main effects of vowel and dialect and the interaction of vowel by dialect were significant for /x/ (vowel: F(3,48)=31.46, p<.001; dialect: F(2,16)=4.31, p<.04 Interaction: F(6,48)=6.38, p<.001). Because of the significant two-way interaction of vowel by dialect, the simple effect of following vowel was tested for each dialect separately for /x/. This was done to determine which vowels cause palatalization in the consonant as indicated by the standard deviation. The Chilean and Mexican dialects showed a significant simple effect of following vowel on the standard deviation of /x/ (Chilean: F(3,21)=60.64, p<.001; Mexican: F(3,21)=18.76, p<.001). Castilian in contrast, did not (F(3,6)=3.56, p>.05). The interaction reflects the fact that for Chilean speakers, /x/ before /e/ and /i/ has similarly very high standard deviation with /a/lower, and /u/ the lowest. For Mexican however the order of /x/ before /i/ has the highest standard deviation, /e/ is intermediate between /i/ and /a/, and /u/ has the lowest. For Castilian however, /a/ is high and with little difference among other vowels. .

To determine which consonants are significantly palatalized relative to which others, a series of pairwise comparisons was performed within each dialect, as for center of gravity above. For Chilean, /x/ before /i/ and /e/ both had a significantly higher standard deviation than /x/ before /a/ (/i/: $F(1,7)=30.15$, $p<.001$; /e/: $F(1,7)=97.68$, $p<.001$). /x/ before /i/ and /e/ had equally high standard deviation and did not differ from one another ($F(1,7)=1.56$, $p>.05$). This indicates that for the Chilean dialect /x/ is affected before both /i/ and /e/.

For the Mexican dialect, /x/ before /i/ had a significantly higher standard deviation than /x/ before /a/ ($F(1,7)=19.51$, $p<.04$), however, /x/ before /e/ did not ($F(1,7)=2.19$, $p>.05$). There was no significant difference between /x/ before /i/ vs. /e/. ($F(1,7)=2.46$, $p>.05$). This indicates that for the Mexican dialect /x/ before /i/ is affected (presumably fronted), but /x/ before /e/ is not. However, since /x/ before /e/ is somewhat intermediate to /xa/ and /xi/ in this dialect, /x/ before /e/ does not differ from /x/ before /i/ either, so the status of /x/ before /e/ in this dialect, based only on the standard deviation measure, is somewhat ambiguous.

For Castilian, results may indicate fronting only before /a/, although the simple effect of following vowel was not significant overall (Figure graph #). This was explored, as with center of gravity above, by using /u/ rather than /a/ as the reference vowel for Castilian. There are only three speakers studied in this dialect so statistical power was limited, however, the statistical results indicate some differences./x/ before /a/ showed a significantly higher standard deviation relative to /x/ before /u/ ($F(1,2)=73.80$,$p<.02$) However /x/ before /i/ was not significantly different than /x/ before /u/ ($F(1,2)=1.18$,$p>.05$). No other pairwise comparisons were tested for this subset of data because the remaining pairs were extremely similar. This indicates that /x/may be somewhat fronted before /a/.

Preceding vowel offset (see figure 4)

The data for the offset of the second formant of the preceding vowel (e.g. /a/ in /**a**#ki, **a**#xu, etc.) was analyzed using the same three factor mixed design ANOVA as above, with the factors consonant (k, x, tS), following vowel (i, e, a, u), and dialect (Chilean, Mexican, Castilian). It is important to note for this measure that the preceding vowel before the consonant is always /a/ (in the word "la" in the frame sentence), regardless of which following vowel condition a measurement is in. That is, any differences among offset F2 measurements reflect not differences in the vowel that F2 is in itself, but rather differences caused by the vowel two segments later and by the effect that subsequent vowel might have on the intervening consonant. All three main effects were significant (consonant: $F(2,32)=11.40$, $p<.001$; vowel: $F(3,48)=93.09$, $p<.001$; dialect: $F(2,16)=5.59$, $p<.03$). The interaction of consonant by dialect was non-significant ($F(4,32)=1.47$, $p>.05$). All other interactions were significant (Vowel by dialect: $F(6,48)=6.22$, $p<.001$; consonant by vowel: $F(6,96)=23.64$, $p<.001$; three way interaction: $F(12,96)=4.70$, $p<.001$).

Because of the significant three-way interaction, the two-factor ANOVA with following vowel and dialect was tested for each consonant separately. For /k/, the main effect of following vowel was significant with the offset F2 of the vowel preceding /ki/ higher than for /k/ before other vowels ($F(3,48)=110.93$, $p<.001$). The main effect of dialect was also significant ($F(2,16)=4.47$, $p<.04$). The interaction of following vowel by dialect was also significant ($F(6,48)=15.30$, $p<.01$), with the Chilean dialect having a more similar F2 offset of preceding vowel between /aki/ and /ake/ than other dialects. Thus the second formant value was higher for both /aki/and /ake/ in the Chilean dialect than before other vowels for /k/.

Because of the significant interaction, simple effects were tested for each dialect separately for F2 going into /k/. (Chilean: $F(3,21)=128.87$, $p<.001$; Mexican: $F(3,21)=25.87$, $p<.001$; Castilian: $F(3,6)=17.36$, $p<.005$). This was done to determine which vowels cause palatalization in the consonant relevant to the measurements of the offset F2 of the preceding vowel.

To determine which consonants are palatalized relative to which others, a series of pairwise comparisons was performed within each dialect, as above. For Chilean, /aki/ and /ake/ both had a significantly higher offset F2 of preceding vowel than /aka/ (/aki/: $F(1,7)=53.286$, $p<.001$; /ake/: $F(1,7)=137.35$, $p<.001$). /aki/ and /ake/ had equally high offset F2 of preceding vowel and did not differ from one another ($F(1,7)=.856$, $p>.05$). This, like the measures above, indicates that for the Chilean dialect /k/ is fronted before both /i/ and /e/.

For the Mexican dialect, /aki/ and /ake/ both had a significantly higher offset F2 preceding vowel than /aka/ (/aki/: $F(1,7)=14.28$, $p<.01$;/ake/:$F(1,7)=8.95$,$p<.03$). /aki/ and /ake/ did not differ from each other ($F(1,7)=8.58$, $p<.03$). This indicates that for the Mexican dialect of Spanish /k/ before both /i/ and /e/ is fronted, on the measure of effect on the offset of the F2 of the preceding vowel.

For Castilian, results appear to indicate fronting before /a/ rather than the other vowels studied (Figure graph). There are only three speakers so statistical power was limited, however, the statistical results indicate several differences. In this case both /aki/ and /ake/ differ from

/aka/ (/aki/: F(1,2)=43.33, p<.03; /ake/: F(1,2)=.32.88, p<.04). However none of /a, e, i/ affected the offset of the preceding vowel's F2 significantly relative to /u/(/i/: F(1,2)=18.67, p=.05; /a/: F(1,2)=14.66, p>.05; /e/: F(1,2)=16.82,p>.05). This indicates that /k/ is somewhat fronted before /i/, /a/, and /e/. The main effects of following vowel and dialect were both significant for /tS/ (following vowel: F(3,48)=3.10, p<.005; dialect: F(2,16)=4.50,p<.04). Their interaction was however non-significant (F(6,48)=.545,p>.05). /tS/ appears to have a higher F2 offset of preceding vowel going into /tS/before /a/ and /u/ relative to the F2 going into /tS/ before /i/ and /e/. Because there was no interaction with dialect for this measure, this interaction was not pursued further.

Both main effects were significant for /x/ (vowel: F(3,48)=45.25, p<.001; dialect: F(2,16)=5.19, p<.03). The interaction, however, was not (F(6,48)=2.07,p=.07). Because of the non-significant trend toward a two-way interaction of vowel by dialect, the simple effect of following vowel was tested for each dialect separately for /x/, to be sure not to obscure any meaningful patterns. This was done to determine which vowels cause palatalization in the consonant which can be observed as early as the second formant preceding vowel offset.

All three dialects showed a significant simple effect of following vowel on the second formant value of the preceding vowel offset before /x/ (Chilean: F(3,21)=28.39, p<.001; Mexican: F(3,21)=36.91, p<.001; Castilian: F(3,6)=5.95, p<.04). The near-significant interaction reflects the fact that for Chilean and Mexican speakers, /axi/ /axe/ have the highest F2 offset of preceding vowel (similar to each other more so in the Chilean dialect than in the Mexican dialect),/a/ following that, and /u/ the lowest. For Castilian however, /x/ before /a/, /i/, and

/u/ seem to be similarly high in second formant value of previous vowel and /x/ before /u/ significantly lower.

To determine which consonants are palatalized relative to which others, a series of pairwise comparisons was performed within each dialect. For Chilean, /axi/ and /axe/ both had a significantly higher F2 offset of preceding vowel than /axa/ (/axi/: $F(1,7)=30.36$, $p=.001$; /axe/: $F(1,7)=21.96$, $p<.003$). /axi/ and /axe/ had equally high values for F2 offset of preceding vowel and did not differ from one another ($F(1,7)=.079$, $p>.05$). This indicates that for the Chilean dialect /x/ is fronted before both /i/ and /e/.

For the Mexican dialect, /axi/ and /axe/ had a significantly higher F2 offset of preceding vowel than /axa/ (/axi/:$F(1,7)=33.77$, $p=.001$;/axe/:$F(1,7)=45.29$,$p<.001$). /axi/ and /axe/ were similar to one another, although they did differ significantly [[which more so??]]($F(1,7)=13.42$, $p<.01$). This indicates that for the Mexican dialect of Spanish /x/ is fronted before both /i/ and /e/ relevant to F2 offset of preceding vowel.

For Castilian, results appear to indicate fronting before /a/ rather than the other vowels studied (Figure graph). There are only three speakers so statistical power was limited, however, the statistical results indicate several differences. Unlike the other dialects, neither /axi/ nor /axe/ differs from /axa/ (/axi/: $F(1,2)=.01$, $p>.05$; /axe/: $F(1,2)=.01$, $p>.05$). However /axa/ and /axi/ both showed significantly higher offset of previous F2 relative to /axu/ (/axi/: $F(1,2)=24.77$, $p<.05$; /axa/: $F(1,2)=28.27$, $p<.05$). /axe/ was not significantly different than /axu/ though ($F(1,2)=11.62$,$p>.05$). This indicates that /x/ is somewhat fronted before /i/ and /a/, but not before /e/, as indicated by effect on the offset of the preceding vowel.

Although not statistically tested, it is clear from the data on the frication noise that /k/ differs greatly from /tS/ in all dialects (see figure 5). The data on spectral moments presented above confirms this.

Conclusion and Discussion

According to the results analyzed, the Chilean dialect of Spanish demonstrates fronting in the environments of /i /and/ e/, while fronting in Mexican Spanish only occurred before /i/, with /e/ patterning more with /a/. In the analysis of Castilian, fronting seemed to occur before/a/in the case that the vowel was fronted. Although data points to possible different interpretations, the results cross-dialectically display trends to support this same basic pattern. One might think it possible for /k/ to palatalize in Chilean all the way to /tʃ/ but it has not due to the acoustical differences shown in the duration of the frication noise of /tʃ/ versus the aspiration noise of /k/.

The first major palatalization wave in the romance language family which caused /k/ to move to /tʃ/ before front vowels and /j/ traced back to Late Latin, seems to be the trend that Chile and Mexico are both following, yet Chile more so in that it palatalizes clearly and equally in the environments of both /i/ and /e/ based on the results of this study. Castilian shows a true difference in trends of palatalization pointing to the dialect specifically following the trend of the second wave of palatalization within a subset of Romance languages and dialects a few centuries later that included palatalization before front vowels and in addition to fronted /a/.

Each dialect has clear trends in palatalization (Chilean before both /i/ and /e/, Mexican before /i/, and Castilian before /a/)and follows these aforementioned trends within the controlled environments shown. This indicates significant differences between the pronunciation and most probably the perception of each of these dialects. The knowledge gathered from such dialectic differences may have implications for the L2 teaching of Spanish and L2 Spanish acquisition. It is relevant in the global world because many L2 learners of Spanish will study in a foreign country that often times will not reflect acoustically the previously perceived sound inventories of L2 Spanish classes. All information gathered within this study is relevant to acquiring a better understanding of these dialects and in turn, the Spanish language.

It is clear that Chilean palatalizes in more environments than the other two dialects, and that Castilian palatalizes in one specific environment in which the other two do not. This points to historical occurrences cross-dialectically during the two main palatalization shifts (first /k/ to /tʃ/ before front vowels and /j/, and second /k/ to /tʃ/ before front vowels and fronted /a/) with both Mexican and Chilean grouping within the first historical shift, and Castilian grouping with the second in addition. This information gives us insight into the phonetic and acoustic representations of these specific sounds in each dialect analyzed, and therefore provides us with more accurate knowledge of Spanish dialectically and allows for a more detailed education of Spanish as administered within L2 classrooms or otherwise. Further investigation into other various dialects may yield valuable results as compared to the information gathered in this study.

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