

The effect of adjacent vowels on the spectrum of back fricatives in Guarani and Spanish

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The aim of this study is to investigate the effect of adjacent vowels on the spectrum of back fricatives in bilingual speakers of Spanish and Guarani. We analyze differences between words containing pairs of identical vowels [i, a, u] within each language and between languages. It has been reported that the constriction location of fricatives is susceptible to vowel context (Shadle & Mair, 1996). However, few studies have investigated this effect on fricatives produced in the posterior portion of the vocal tract. Shadle (1995), for instance, studied the role of the vowel [i] in the production of palatal and velar fricatives in German. She observed that the vowel [i] attracts the fricative to the palatal region.

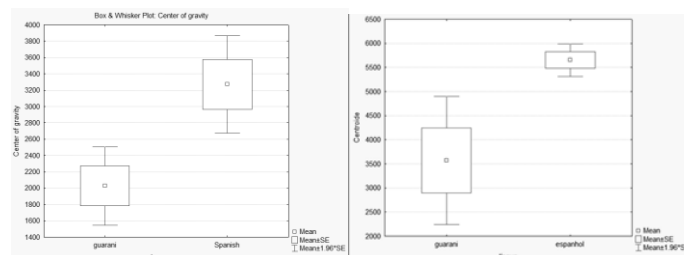
Abul-Al-Makarem & Cooper (2005) and Al-Khairy (2005) investigated the acoustic characteristics of fricatives in Arabic. They reported a minimal effect of the vowel on the fricatives' spectrum. Probably, the effect of the vowel in Arabic is smaller due to its larger phonemic back obstruent inventory. On the other hand, based on acoustic data on three varieties of Spanish, Jiquilin-Ramirez (2010) pointed out that the behavior of the fricative spectrum is governed by adjacent vowels. This indicates that the degree of co-production between the fricative and the adjacent vowels is high. Iskarous et al (2012) reached the same conclusion based on articulatory data of Navajo.

In any case, this study is the first spectral investigation of the same effect in bilingual speakers. Corvalan & Canese (1987), among others, describe the back fricative of Paraguayan Spanish as a velar phoneme and the back fricative of Guarani as glottal. Based on the fact that these segments have distinct phonological status in each of these languages, we raise the following questions: how VCV co-articulation occurs in each language? In the same language, are there significant spectral differences in fricative production by bilingual subjects?

To investigate these issues, we recorded four bilingual subjects, three females and one male. All subjects are native speakers of Paraguayan Spanish and Guarani, from the metropolitan region of Asuncion, Paraguay. The *corpus* consists of 160 target words or phrases inserted in carrier sentences. In each word/phrase, the fricative was preceded and followed by one of the vowels [i, a, u]. According to the methodology described in Forrest et al. (1988) and Jongman et al. (2000), we extracted the first four spectral moments of the fricative (i.e. center of gravity, standard deviation, skewness and kurtosis) and compared: i) the means of the spectral moments in three vowel contexts for the same language; ii) their means in the same vowel in different languages. Kruskal-Wallis non-parametric test was used for the first comparison, followed by Student-Newman-Keuls post-hoc test. For the second comparison, the Student's t test and the Wilcoxon signed-rank test were used.

Cross-linguistic comparisons (figure 1) reveal a significant difference in the center of gravity of general mean of vowels ($t = -3,6751$, $df = 6$, $p = 0,0104$). However, comparative results by vowel show a significant difference in the center of gravity of [i] ($U = 2.3094$, $p = 0.0209$) only.

Figure 1: Center of gravity of general vowels (left) and of vowel [i] (right) in Guarani and Spanish



The intralinguistic comparisons showed that there are significant differences in the spectral moments, especially for pairs of fricatives produced with [i] and [u], both in Spanish and Guarani.

For Guarani, center of gravity ($H = 8.1154$, $df = 2$, $p = 0.0045$), skewness ($H = 6.9304$, $df = 2$, $p = 0.0108$) and kurtosis ($H = 6.2692$, $df = 2$, $p = 0.0142$) presented significant differences between [i] and [u]. However, the significance of standard deviation ($H = 6.9615$, $df = 2$, $p = 0.0624$) was marginal. Standard deviation ($H = 6.9615$, $df = 2$, $p = 0.0108$) was, in turn, significant to differentiate the vowel contexts [a]_[a] and [i]_[i].

For Spanish, center of gravity ($H = 9.2692$, $df = 2$, $p = 0.0024$), skewness ($H = 7.7426$, $df = 2$, $p = 0.0070$) and kurtosis ($H = 6.0596$, $df = 2$, $p = 0.0142$) showed significant values to the difference between [i] and [u]. Figure 2 summarizes the intralinguistic findings:

Figure 2: Significant spectral moments in Guarani and Spanish

Guarani	Center of gravity	Standard Deviation	Skewness	Kurtosis	Spanish	Center of gravity	Standard Deviation	Skewness	Kurtosis
[a]_[a] x [i]_[i]		X			[a]_[a] x [i]_[i]				
[a]_[a] x [u]_[u]					[a]_[a] x [u]_[u]				
[i]_[i] x [u]_[u]	X	marginal	X	X	[i]_[i] x [u]_[u]	X		X	X

To sum up, it seems that high vowels have an important role in VCV back fricative co-articulation within each language. Yet, between languages, this only occurs with the vowel [i]. Differences in vowels center of gravity values, between languages, indicates constriction location more anterior for Spanish fricatives, compared with Guarani. To better interpret the effect of cross-linguistic articulatory vowel differences on the back fricative, analyses of the vowel triangle of each language and analyses of movement of higher formants of each vocalic context are under way.

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