Increasing Periodicity to Reduce Similarity: An Acoustic Account of Deassibilation in Rhotics

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1. Introduction

Alternations and changes from trills to assibilated rhotics have been documented in several Latin American Spanish varieties (e.g. Vidal de Battini 1955, Rissel 1989). Beyond the sociolinguistic variables that may have triggered this change, assibilation can be accounted for by recent articulatory studies on trills (Solé et al. 1998, Solé 2002). These studies show that trills require very precise aerodynamic conditions for their production, and if those conditions are not met, and oro-pharyngeal pressure increases, an assibilated rhotic is produced instead. The change in the opposite direction, which is the one that concerns us here, should be less likely, since speakers would have to learn to master, among other parameters, the necessary aerodynamic conditions to produce a trill. However, this process has also been documented, again triggered by specific sociolinguistic conditions (e.g. De los Heros 1997, Colantoni 2001). Given the seemingly equal likelihood of the bi-directionality of the process, several explanations are possible. It could be hypothesized either that the sociolinguistic factors override the phonetic motivations or that the articulatory studies are not accurate. A third hypothesis will be proposed here, namely that it is not the trill but rather an approximant rhotic that is the end-point of this process. Approximants differ from fricatives in the absence of a turbulent airstream, which could be due to: (i) a lack of the articulatory precision required to produce a fricative; (ii) an insufficiently narrow constriction; (iii) a combination of (i) and (ii) (Martínez Celdrán 2004: 208). As such, a change from an assibilated to a non-assibilated rhotic involves an increase in periodicity that is achieved by decreasing the degree of constriction.

Loss of assibilation in rhotics, illustrated in (1), is then, the mirror image of another change that is taking place in some areas of Argentina (e.g. Corrientes, Cordoba, Entre Rios), including some of the locations under study. There the existing non-assibilated palatals are being substituted by assibilated post-alveolars, as shown in (2) below:

(1) A[ɹ̌]iba > a[r]iba *arriba* 'up'

(2) Ca[ʝ]e > ca[ʒ]e *calle* 'street'

I have proposed elsewhere (Colantoni 2001, to appear) that these parallel changes, which resemble a dissimilatory process, are motivated both by external factors (e.g. the influence of the Buenos Aires dialect,[1] which has only trills and assibilated palatals in its repertoire), and by the acoustic and perceptual similarity between the existing assibilated rhotics and the new assibilated post-alveolars. However, detailed acoustic characterizations of assibilated rhotics are not abundant, and, as a consequence, comparisons with assibilated post-alveolars are not accurate. Thus, the first goal of the present paper is to characterize the rhotics acoustically, using parameters that specifically quantify the

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[1] The Buenos Aires dialect is spoken by more than a third of the population of Argentina, and is almost the only variety used in mass media.

dimension that is being affected in the process, i.e. the degree of periodicity and possibly the place of articulation of the new and existing sounds. This characterization will constitute a point of departure for a future comparison between the new and existing rhotics and the new and existing post-alveolar sibilants in these same varieties. The second aim is to provide an acoustic account of the process of loss of assibilation, and demonstrate that it involves an increase in periodicity whose end-point is an approximant rhotic.

The rest of the paper is structured as follows. First, I summarize briefly the acoustic characteristics of trills (§2) and post-alveolar sibilant fricatives (§3). Then, I discuss the hypotheses (§4) and methodology (§5). Finally, the presentation of the results (§6) is followed by discussion (§7) and a brief conclusion.

2. Acoustic studies on trills

The standard Spanish trill has been described as consisting of two to five closures (Recasens & Pallarès 1999), with the most frequent realizations involving probably only three (Quilis 1993, Blecua 2001, Solé 2002). Some variation in its realization has been observed. For instance, Blecua (2001) indicates that around 4% of all realizations are approximants, and Quilis (1993) interestingly points out that some frication may be present after the last closure.

As concerns the trill duration, Mendoza et al. (2003) report that the trill is one of the longest sounds in their study (only shorter than voiceless fricatives), ranging in duration from 146 ms (medial position) to 162 ms, in initial position. This study, however, was based on non-sense words, and a shorter mean duration (i.e. 85 ms) was reported for real words (Quilis 1993). The duration of the trill is not only affected by its position in the word but also by the following vowel. Solé (2002) observes that trills are shorter in the /i/ than in the /a/ context; but this may depend on the number of closures (see Recasens & Pallarès 1999). As for its quality (see Fant 1960, Quilis 1993), Borzone de Manrique (1980) reports a mean value of 500 Hz, 1550 Hz and 2500 Hz for F1-F3, respectively. The quality is also subject to coarticulatory effects, mainly with the following vowel (Recasens & Pallarès 1999).

Studies dealing with the degree of periodicity of the Spanish trill are scarce. The only source is Gurlekian et al. (1989), which focuses on the description of the whole consonantal inventory, as opposed to trills in particular. According to this study, Buenos Aires Spanish trills are characterized by having a zero-crossing rate in the range of 1200-1900, a correlation coefficient of 0.35-0.89, and a cepstral peak amplitude that ranges from 0.09 (/i/ context) to 0.14 (/a/ context).

Studies on fricative trills are fewer, given that assibilated rhotics are infrequent cross-linguistically, and even their mere existence has been called into question. Maddieson (1984:80) argues that there may be no phonetic basis for distinguishing fricative trills from voiced retroflex sibilants. Ladefoged and Maddieson (1996:228-9) treat them as a subtype of rhotic (i.e. fricative trills) and suggest that they consist of a phonetic sequence of a trill and a fricative. Beyond this debate regarding their status as fricatives or fricative trills, assibilated rhotics in Spanish do pattern with trills, and, as mentioned before, they alternate with them in several Latin American and Peninsular dialects. Quilis and Carril (1971) constitutes the reference point for acoustic studies on Spanish fricative trills. The authors report data from four native speakers of different Latin American Spanish varieties. They conclude that fricative trills are devoiced 12.5% of the time, have a duration ranging from 80-180 ms, an F1 in the range of 457-557 Hz, an F2, which is not always clearly defined, in the 1300-1700 Hz range, and finally, and more importantly for the present study, a frication noise that starts in the F2 range. In a previous study (Colantoni 2001), I characterized a small number of fricative trills in Argentine Spanish, and obtained results which were generally consistent with those previously reported. These studies, however, neither report periodicity measurements for fricative trills nor present a detailed analysis of the spectral properties of the sound. These measurements are crucial to allow a careful comparison with post-alveolar sibilant fricatives.

3. Acoustic studies on post-alveolar sibilant fricatives

A number of acoustic parameters have been proposed to classify fricatives, including durational properties (e.g. Behrens & Blumstein 1987), the amplitude of the frication noise (e.g. Strevens 1960, Behrens & Blumstein 1988), and the spectral properties of the noise portion (e.g. Strevens 1960, Forrest et al. 1988, among others). It has been observed that the amplitude of the frication noise and durational properties do not contribute to the differentiation of coronal fricatives (Evers et al. 1998), whereas the spectral properties of the noise portion seem to be the relevant parameter for the discrimination of sibilants by adult speakers (e.g. Borzone de Manrique & Massone 1981, Nittrouer 2002). In particular, it has been argued that discrimination is better at the midpoint of frication (Nittrouer & Miller 1997, Evers et al. 1998).

Two spectral properties have been shown to classify successfully alveolar and post-alveolar fricatives, namely the location of the spectral peak (e.g. Strevens 1960) and the four spectral moments (Forrest et al. 1988, Flipsen et al. 1999, Jongman et al. 2000, Tabain 2001). The spectral moments aim at capturing "both local (mean frequency) and global (spectral tilt and peakedness) aspects of speech sounds" (Jongman et al. 2000: 1253). The first moment or mean provides information about the average concentration of energy (Forrest et al. 1988, Jongman et al. 2000). The second moment or variance indicates the range in energy concentration. There is some disagreement, however, about the adequacy of this parameter for the description of obstruents. According to Forrest et al. (1988), the second moment is not useful for discriminating obstruents, but Jongman et al. (2000) suggest that it is the best parameter for place classification. The third moment or skewness provides information about the tilt of the energy distribution (Forrest et al. 1988). A value of '0' points to a symmetry around the mean; 'positive' values denote that the right tail of the distribution extends further than the left tail, whereas a 'negative' skewness implies that the left tail extends further than the right tail (Jongman et al. 2000). The fourth moment or kurtosis indicates the peakedness of the energy distribution (Forrest et al. 1988); negative values are an indication of a flat spectrum, while positive values are a sign of a spectrum with clearly defined peaks (Jongman et al. 2000). Although most researchers agree that moments constitute a reliable measurement, some concerns have been raised (see Evers et al. 1998) about their adequacy for describing contrasts in speech. Moment analyses have not been applied to the analysis of Spanish sibilant fricatives, so for this study the values reported for English will constitute the point of comparison for the values obtained for rhotics. The first moment for English [ʃ,ʒ] is in the range of 4500-5300 Hz (Jongman et al. 2000, Tabain 2001); the second moment is 3300 Hz (Jongman et al. 2000); skewness is 0.693 (Jongman et al. 2000); the fourth moment is 0.42 (Jongman et al. 2000).

As mentioned, Spanish post-alveolar sibilant fricatives have not received much attention, probably because they are present only in a handful of varieties. Buenos Aires Spanish is one of these, and it has been described as having both voiced and voiceless post-alveolar fricatives in allophonic distribution, and most likely, in free variation (Wolf & Jimenez 1979, Wolf 1984). The only acoustic study on Buenos Aires Spanish sibilants reveals that these segments have spectral peaks between 3000 and 5500 Hz (Borzone de Manrique & Massone 1981).[2] Finally, information about the degree of periodicity of these sibilants is scarce, although there is a general study on Buenos Aires Spanish (Santagada & Gurlekian 1989), which, again, will constitute our source of comparison. The authors report mean values of 0.08 for the cepstral peak amplitude of voiced and voiceless post-alveolar sibilants.

In summary, post-alveolar sibilants have been widely studied in other languages, and it has been shown that the noise portion (as opposed to the transitions) provides enough evidence to classify and discriminate between them. In particular, studies on English sibilants have shown that the four spectral moments are a reliable parameter to characterize their place of articulation, and those studies will guide us in elaborating the hypotheses and evaluating the results. As for periodicity measurements, we will rely on the only previous study of Buenos Aires Spanish.

[2] Acoustic data on Buenos Aires Spanish are of extreme relevance here. I have shown elsewhere that contact with this variety seems to be triggering the changes under analysis (see Colantoni 2001, to appear).

4. Hypotheses

The general hypothesis behind this study is that the dissimilatory process observed in Argentine Spanish is motivated in part by the acoustic similarity between the existing assibilated trills and the new assibilated post-alveolar consonants that are spreading into the areas under study (i.e. Corrientes and San Juan). In particular, this similarity should be reflected in the periodicity measurements (i.e. cepstral values) and in the place of articulation (similar values for the spectral moments).

Secondly, it is hypothesized that this change implies a reduction of noise and an increase in periodicity. Thus, a higher rate of voiced variants, shorter duration, and a higher cepstral peak amplitude are expected for those speakers who represent a more advanced stage in the process.

Thirdly, it is proposed that the increase in periodicity will take place before the control of the tongue-gestures characteristic of the trill, since it has been shown that very precise aerodynamic and articulatory conditions are necessary for trilling to occur (Solé 2002). If a less noisy segment is the target, then, it is expected that speakers should produce an increasing number of approximant variants, and that trilling would take place only at very advanced stages.

5. Methodology

The data for the present analysis come from fieldwork recordings collected by the author between 1994 and 1997 for the linguistic-anthropologic atlas of Argentina, a project directed by O. Kovacci. Interviews were conducted using a traditional dialectological questionnaire[3] supplemented by narratives elicited with sociolinguistic techniques.[4] Recording took place in a quiet place, using a tape-recorder with metallic tape and a unidirectional lavaliere microphone.

For the aforementioned project, a total of forty locations in the provinces of Corrientes (26), San Juan (19), Misiones (2), and Entre Rios (3) were surveyed. Only 8 of those locations were selected here based on the results of either my previous studies (Colantoni 2001, to appear) or other studies on Argentine Spanish (Vidal de Battini 1955, 1964).[5] The criterion for this selection was to analyze data representative of different stages in the process of loss of assibilation, ranging from areas with maintenance of assibilation and a preference for voiceless rhotics in the western province of San Juan (Jachal –J-, Rodeo –R-, Valle Fertil –VF-, Villa Krause –VK-) to locations with incipient deassibilation (Bella Vista –BV-, Paso de los Libres –PL-) or more advanced stages in the change (Alvear –A-, San Miguel – SM-) in the northeastern province of Corrientes. It is important to point out here that the selection of the locations was based on previous auditory analyses that were corroborated through the acoustic study of a small set of tokens. The speech of the eight male speakers[6] representative of those locations is analyzed here. The speakers were recruited following the general directions of the project; namely, they were native and lifelong residents of the locations under study, with no secondary education and ranging in age between 25 and 55.

In order to perform the analysis, tapes were digitized at 44100Hz/16-bit and then downsampled at 22050 Hz/16-bit. Words containing the target sounds[7] were extracted from the approximately two-hour long interviews. A total of 789 tokens were obtained, and 690 were acoustically analyzed after excluding 99 tokens for recording quality. All tokens were transcribed both by the researcher and a

[3] This questionnaire aimed at eliciting isolated words organized in several semantic fields, such as body parts, tools, plants, animals, etc.

[4] The narratives elicited included the description of local legends and important events, such as the 1977 earthquake in San Juan.

[5] For my previous studies, I only analyzed data from two locations in San Juan (Valle Fertil and Jachal). In consequence, to balance the number of locations from the same province, I had to rely on previous descriptions of assibilation in rhotics (e.g. Vidal de Battini 1964).

[6] Only male speakers were selected in order to facilitate the comparison with existing studies on post-alveolar sibilants.

[7] It is important to point out here that only assibilated rhotics in singletons were analyzed, since they are the only ones that can be compared with post-alveolar sibilants, given their distributional properties. Thus, the realization of rhotics in clusters in words such as *otro* 'other' is excluded from the present analysis.

graduate assistant for three realizations: fricative trill (voiced and voiceless) and trill. Each token was coded for linguistic (stress, following and preceding segments), and extra-linguistic (location) variables. Results were exported to Excel. Statistics, which were calculated with SAS 8.02 (significance set at 0.05), were only performed on a subset of the data analyzed (N= 532), in an attempt to have a comparable number of tokens per speaker, including a similar number of tokens in each of the cells relevant for the analysis.

To test the hypotheses, four different measurements were taken. First, the duration of the target segments was analyzed, in order to be able (i) to compare the variants against previous descriptions of assibilated and non-assibilated rhotics; and (ii) to determine the percentage of the duration of the segment that was voiced. Duration was measured using both the waveform and the spectrogram with Praat 4.0.41 (Macintosh version). The onset of the rhotic was determined by a change in the waveform, a drop in intensity, and a drop in F1, whereas the offset was set at the point where a change in the waveform, an increase in intensity, and an increase in F1 were observed. All measurements were taken at zero crossings. Secondly, the percentage of voicing (i.e. the duration of the F0 as a proportion of the duration of the whole segment) was measured. These values, which are expressed in percent of voicing, were obtained with Praat 4.0.41 (Macintosh version); and results were verified with Anagraf 2.0 (Gurlekian 1997), given that this program uses three different methods for calculating the F0. Thirdly, in order to determine the degree of periodicity of the target segment, the cepstral peak amplitude was measured for all tokens. This method has been applied to determine the periodicity of Buenos Aires Spanish consonants and vowels (Santagada & Gurlekian 1989, Gurlekian et al. 1989), providing thus a useful source of comparison. Cepstral peak values were calculated over a 25ms window, centered at the center of the sound using Anagraf 2.0 (Gurlekian 1997). A high peak-amplitude (values closer to 1) signals the presence of a periodic component, whereas lower values suggest the existence of noise in the signal. Finally, for those tokens whose cepstral peak values were lower than those reported for trills in Argentine Spanish and identical or lower than those observed for post-alveolar sibilants in the same variety (i.e. ≤ 0.08), the spectral moments were calculated. Two reasons motivated this decision; first, moment analysis has been proposed as a method of classifying obstruents, and in consequence, all rhotics that exhibited cepstral values above those reported for obstruents had to be excluded from the analysis. Second, in order to test the hypothesis that the change is motivated by the acoustic similarity between the existing assibilated rhotics and the new assibilated post-alveolar sibilants, it is important to verify that the comparison relies on segments with similar degrees of periodicity before testing their similarity in place. Thus, for the subset of target sounds that fulfilled the aforementioned requirement, three of the four moments (center of gravity or mean, second moment or variance, and skewness) were obtained.[8] In order to perform the analysis, a 40ms Hamming window was extracted from the midpoint of the segment following procedures established in previous analyses of fricatives (Evers et al. 1998, Flipsen et al. 1999, Jongman et al. 2000), then a 512-FFT spectrum was obtained, and finally the moments were measured with Praat 4.0.41 (Macintosh version). In the next section, the results of these measurements will be presented in the order they were discussed here.

6. Results

6.1. Auditory transcription

Results of the auditory transcription reveal that 26% of the tokens (n= 178) were interpreted as standard trills, and, among these, 70% of them were observed in the four locations in the province of Corrientes.[9] When those auditory transcriptions were verified against spectrographic analyses, it was observed, however, that only 5 tokens were indeed trills, i.e. they consisted of more than one closure. The remaining 173 tokens, as illustrated in Figure 1, constituted instances of approximant rhotics.

[8] The kurtosis was excluded from the final calculations, given that in previous studies (Jongman et al. 2000) it only characterized different places of articulation when measured at the onset of the fricative.

[9] Indeed, the number of trills identified by each of the transcribers was even higher, but only the tokens for which both transcribers agreed are reported here.

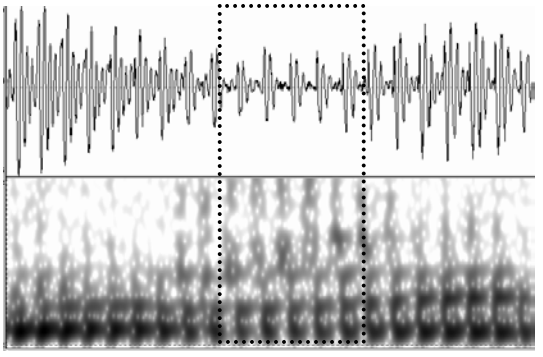

Figure 1: Spectrogram and waveform of the approximant rhotic in the word *correntino* 'from Corrientes' (Bella Vista, Corrientes).

As for the assibilated variants, voiced realizations (see Figure 2) were the most frequent, representing 57% of the total (n= 395), whereas the voiceless rhotic (see Figure 3) constitutes 17% (n= 117) of all the rhotics. Both assibilated variants were transcribed in all of the locations under study.

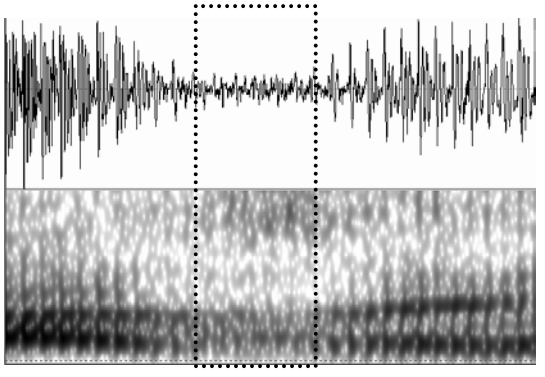

Figure 2: Spectrogram and waveform of the voiced assibilated rhotic in the word *arreglan* 'they fix' (Rodeo, San Juan).

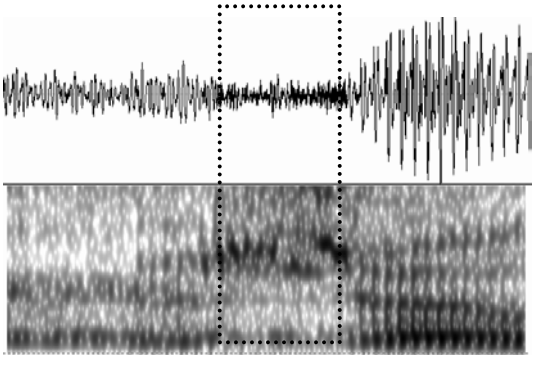

Figure 3: Spectrogram and waveform of the voiceless assibilated rhotic in the word *(en) Rodeo* (Rodeo, San Juan).

6.2. Duration

Mean duration in the sample ranges from 60ms (SM, BV and R) to 100ms (VF). A one-way ANOVA test revealed significant inter-speaker differences ($F(7, 532) = 26.68$), and results from a post-hoc Fisher's LSD test indicate that there are three distinct groups of speakers, classified according to a decreasing duration of the rhotic: (1) VF; (2) VK, PL; (3) AL, BV, SM, R, J. The generalizations

that emerge from this analysis are not surprising; locations, such as VF, where voiceless assibilated rhotics were observed in previous studies exhibit longer duration, whereas rhotics are shorter in locations where an increasing number of "trills" was reported previously (see Colantoni 2001). Indeed the shorter duration in this latter case is the result of the fact that speakers are actually producing approximants, as opposed to trills, which are longer segments (see Mendoza et al. 2003). Duration is significantly affected by stress ($F(2, 532) = 5.83$, $p=0.0032$); results of a post hoc Fisher's LSD test indicate that the rhotic is longer in stressed than in pre-tonic and post-tonic syllables. The following vowel, however, does not significantly affect duration.

6.3. Voicing

Mean voicing for rhotics in the sample ranges from 13% (in VF) to 92% (in A). The percentage of voicing differs significantly across speakers ($F(7, 532) = 40.68$); but it is not significantly determined by the linguistic variables under analysis ($F(2, 532) = 1.19$). Results of a post-hoc Fisher's LSD test indicate that there are three distinct groups in terms of the percentage of voicing, which roughly parallel the grouping observed in the previous section. The speaker from VF, as mentioned, exhibits the lowest percentage of voicing and constitutes a group himself. The second group is formed by two speakers from Corrientes (PL, SM) and two from San Juan (VK, J). Finally, the highest percentage of voicing was observed in two locations in Corrientes (AL, BV) and one in San Juan (R), which generally corresponds to the auditory transcriptions reported in previous works. The only linguistic variable that significantly affects voicing is 'stress' ($F(2, 532) = 3.55$, $p=0.02$). Results of a Fisher's LSD post-hoc test show that the rhotic is more voiced in stressed and pre-tonic syllables than in post-tonic ones.

6.4. Cepstral peak amplitude

The cepstral peak amplitude was the measurement chosen to determine the degree of periodicity of the rhotics in the sample. Again, higher values indicate the presence of more periodic segments whereas lower values signal a lower degree of periodicity, and as such the presence of assibilated rhotics.

The results obtained are displayed in Figure 4. Cepstral peak values for these Spanish varieties range from 0.06 to 0.1, i.e. from values that are equal or lower to those reported for post-alveolar sibilants (Santagada & Gurlekian 1989) to those that are in the range of trills. A one-way ANOVA test indicates that inter-speaker differences are significant ($F(7, 532) = 13.22$, $p<0.0001$). Results of a post-hoc Fisher's LSD test revealed two clear groups. As expected, a higher cepstral peak is observed in three locations in Corrientes (BV, A, SM), whereas values associated with sibilants are noted in three locations in San Juan (VF, VK, and J). Two speakers constitute an exception to this trend: PL and R. The results in Table 1 show that PL is actually the only exception to the overall tendency. The speaker from Rodeo behaves similarly to two other speakers in San Juan (i.e. J, VF), whose realizations tend to show low periodicity levels in 50% or more of the instances. The speakers from Corrientes, on the other hand, tend to have realizations with cepstral values equal to or above 0.09 in more than 60% of cases. Finally, the cepstral peak amplitude is not affected by any of the linguistic variables considered here.

Table 1: Percentage of more periodic (cepstral values ≥ 0.09) and less periodic (cepstral values ≤ 0.08) by location.

Location		+ Periodic (%)	-Periodic (%)
Corrientes	A	76	24
	BV	71	29
	PL	32	68
	SM	67	33
San Juan	J	48	52
	R	45	55
	VF	35	65
	VK	55	45

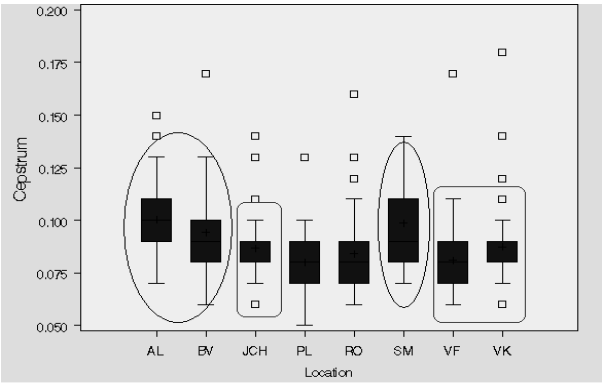

Figure 4: Box-plots of the cepstral peak values for all the speakers in the sample. The two clear groups that emerge from the analysis are marked with ellipses (three speakers from Corrientes) and rectangles (three speakers from San Juan).

Interestingly, when the cepstral peak values are compared against the results of the auditory transcription, we conclude that segments that were transcribed as trills tend to have cepstral values that are equal or higher than 0.1. This suggests that there might be a periodicity threshold for the perception of a trill even in the absence of the precise articulatory gestures.

6.5. Spectral moments

The first spectral moment ranges from a mean of 1300 Hz in SM to 2989 Hz in VF (see Figure 5). One-way ANOVAs were conducted to determine the role of the variables 'speaker', 'stress', and 'following vowel'. Results indicate that only inter-speaker differences are significant ($F(7, 250) = 25.15$; $p < 0.0001$).[10] The overall lower values obtained here may be interpreted as a sign of a more retracted articulation for the assibilated rhotic, when compared to English post-alveolar sibilants. Results could also be attributed to methodological differences, which will be discussed in section 7 below.

[10] The low values obtained in A and SM may also be attributed to the small number of tokens that were analyzed for these speakers, given that the majority of their realizations were highly periodic.

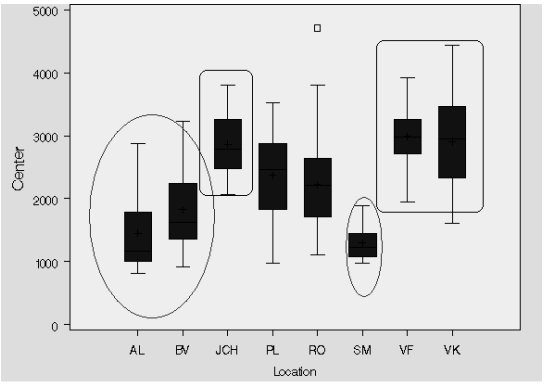

Figure 5: Box-plots of the first spectral moment for all the speakers in the sample. The two groups that emerge from the analysis are marked with ellipses (three speakers from Corrientes) and rectangles (three speakers from San Juan).

Results for the second moment or variance are displayed in Figure 6. As was the case for the first moment, three one-way ANOVAs were calculated to test the role of the variables 'speaker', 'stress', and 'following vowel'. Again, results show that only inter-speaker differences are significant ($F(7, 250) = 42.29$, $p<0.0001$). Post-hoc Fisher's LSD tests confirm that there are no significant differences among the four speakers from Corrientes. One of these speakers (PL) does not differ significantly from one of the speakers in San Juan (VF). On the other hand, three of the speakers from San Juan can be grouped together (J, VF, R), and R does not differ significantly from the fourth speaker from the province (i.e. VK). The values obtained for the four speakers in San Juan are in the range (although slightly lower) of those observed for English post-alveolar sibilants.

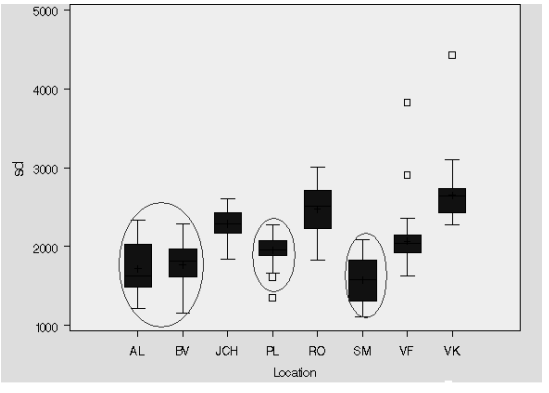

Figure 6: Box-plots of the second spectral moment for all the speakers in the sample. Speakers from Corrientes, which constitute a clear group, are marked with ellipses.

Finally, the skewness values for all the speakers in the sample are positive (see Figure 7), which indicates a concentration of energy in lower frequencies, consistent with what has been reported previously for the Spanish fricative trill (see Quilis & Carril 1971). Again, skewness results are significantly affected only by the variable 'speaker' ($F(7, 250) = 23.25$, $p<0.0001$). For three of the speakers (J, PL, and VF) the values are close to 0, which suggests a concentration of energy around the mean (see Forrest et al. 1988, Jongman et al. 2000). In addition, these values are almost identical to

those reported for the English post-alveolar sibilants (see Jongman et al. 2000). With the exception of SM,[11] the remaining four speakers have statistically similar but higher values.

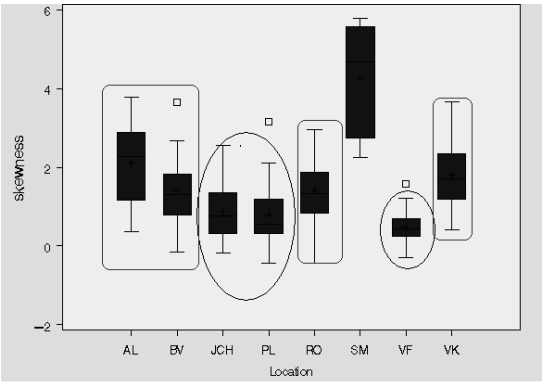

Figure 7: Box-plots of the third spectral moment for all the speakers in the sample. The two groups that emerge from the analysis are marked with ellipses (J, PL, VF) and rectangles (A, BV, R, and VK).

6.6. Summary

As concerns duration, voiceless rhotics are the longest in the sample, although mean duration does not exceed 100 ms, which is in the mid-range of the values reported for trills. The mean duration is shorter than that of the trill for five locations, three of them in Corrientes. The percentage of voicing is lower in San Juan (with the exception of Rodeo). In all the locations in Corrientes, the rhotic is voiced for 60% or more of its duration. Cepstral peak amplitude values range from 0.06-0.08 (values reported for post-alveolar fricatives) to 0.1 (value reported for trills). Most of the speakers from San Juan have significantly lower cepstral values than the speakers from Corrientes. Finally, the moment analysis reveals that: (i) the center of gravity was the highest in San Juan, but still consistently lower than for English post-alveolar sibilants; (ii) speakers could be classified into two groups corresponding to the two provinces, according to the variance results; (iii) the concentration of energy tends to be in the lower frequencies, as reported before (see Quilis & Carril 1971).

7. Hypothesis evaluation and discussion

The first hypothesis, which stated that the change from assibilated rhotics to trills was motivated in part by their phonetic similarity to post-alveolar fricatives, is partially confirmed. As discussed, periodicity measurements for most of the speakers in San Juan, where the change has either not started or is incipient, coincide with those reported in the literature for Buenos Aires Spanish post-alveolar sibilants (Santagada & Gurlekian 1989). Thus, as concerns the periodicity dimension, San Juan rhotics are similar to Buenos Aires post-alveolar sibilants, whereas Corrientes rhotics are, in general, more periodic. Similarities on the place dimension are more difficult to determine. For the same speakers, values for the third spectral moment are similar to those reported for post-alveolar sibilants but results for the first and second moments are still consistently lower, in particular for the center of gravity. Thus, although the general trend points towards similarities in place, it is difficult to determine with the available data whether the discrepancies signal real differences in place of articulation (i.e. a retroflex articulation in the province of San Juan) or are purely methodological. For example, Jongman et al. (2000) calculated the spectral moments using four 40ms windows located at the onset, middle, offset and transition into the vowel. They report only mean results in a table while the measurements obtained for each of the four windows are displayed in a chart. Results obtained here differ even selecting the values for their second window, i.e. that located in the center of the segment. However, we are also reporting fieldwork data obtained mostly from running speech, and, more importantly, we

[11] This speaker should have probably been excluded from the computation of the spectral moments since he produced only 8 tokens that could be considered here, given that the rest of his realizations were highly periodic.

are comparing different languages.

The second hypothesis is confirmed by the results. It is possible to establish that the change involves an increase in periodicity, since (i) cepstral values are significantly higher for speakers who represent a more advanced stage in the change, and those values are in the range of those reported for Buenos Aires trills (Gurlekian et al. 1989); (ii) for these same speakers, rhotics are voiced for at least 60% of their duration; and (iii) are shorter in duration.

The third and final hypothesis is also confirmed by the results, which show that an increase in periodicity takes place before trilling. As we observed, for those speakers representing a more advanced stage in the process, periodicity is higher but this increase in periodicity is not accompanied by control of the aerodynamic settings necessary to produce trilling. This is evident in the almost categorical absence in the spectrograms of the characteristic pattern of trills, i.e. the alternation of brief closures and openings, and is also reflected in the shorter duration of the segment. Thus, it is possible to hypothesize that in order to achieve the target sound, which is more periodic in nature, speakers are reducing the degree of constriction characteristic of the fricative rhotic. The result is a segment which is voiced and has the manner of articulation of other existing segments in their inventory, i.e. an approximant.

Thus, results support the analysis of fricative and approximants rhotics as members of an articulatory continuum in opposition to standard trills, and, as such, they are consistent with recent studies (see Solé 2002) that demonstrate that there is a qualitative difference between trills and approximants/fricatives. These results also mirror the variation between fricative and approximant rhotics observed in other Romance varieties, such as European and Quebec French (Straka 1979, O'Shaughnessy 1982). The present findings, however, call for a reanalysis of similar processes reported for other Spanish varieties, such as Peruvian Spanish (e.g. De los Heros 1997). Given that approximants, and not trills, seem to be the end-stage of the process, it would be worth revisiting previous reports of deassibilation using acoustic techniques.

From a perceptual point of view, there seems to be evidence for grouping approximants and trills in opposition to fricative rhotics. The approximant shares the degree of periodicity with the trill, and, thus, it may be perceived as a trill. This is suggested by the fact that segments transcribed as trills had periodicity values within the trill range. The perceptual similarity hypothesis is also supported by previous studies on other Spanish varieties (see Hammond 1999, Blecua 2001) that showed that dialects traditionally characterized as having a trill had variable rates of approximant realizations. This hypothesis, however, has to be tested with perceptual experiments that consistently manipulate the degree of periodicity of the stimuli.

The similarity between fricative rhotics and post-alveolar/retroflex sibilant fricatives is a matter that deserves further study. Maddieson (1984) claims there are no actual differences between them. Quilis and Carril (1971) as well as Ladefoged & Maddieson (1996) believe that they differ mainly in the presence of trilling and in the frequency of the noise spectrum. The results obtained here indicate that there are no differences in the degree of periodicity (see Santagada & Gurlekian 1989) of assibilated rhotics and post-alveolar sibilants. As concerns the place of articulation, the moment analysis shows similarities in skewness and variance (at a lesser degree) with English sibilants (see Jongman et al. 2000), but data are still lacking both for Buenos Aires post-alveolar sibilants and for the new post-alveolar sibilants that some of these same speakers are producing. Moreover, it would be interesting to replicate this study for other Spanish varieties (e.g. Ecuadorian; see Argüello 1978), and other languages (e.g. Czech; see Dankovičová 1999), that have a stable opposition between assibilated rhotics and palato-alveolars. A similar study would lead to a better understanding of the acoustic parameters associated with these segments in the periodicity and place dimension. Ecuadorian Spanish and Czech, however, differ from Argentine Spanish from a sociolinguistic point of view, since in the case under study the change is likely to be triggered by contact with Buenos Aires Spanish, which has no assibilated rhotics and assibilated palato-alveolars in its inventory.

8. Conclusions

The present study demonstrates that rhotics in Argentine Spanish are part of a continuum that ranges from fricatives to approximants, similar to what has been described in other Spanish and Romance varieties. The extremes of this continuum resemble sounds that are emerging in these Argentine varieties. On the one hand, the fricative rhotics are acoustically (and probably articulatorily) similar to the new post-alveolar sibilants. On the other hand, approximant rhotics are similar acoustically (and probably perceptually) to the standard trill, as concerns the degree of periodicity. Thus, results suggest that although the mastering of the trill might be impaired by articulatory constraints, the target is approached by decreasing the degree of constriction, yielding to a voiced approximant. As such, increasing the periodicity in a fricative trill may lead to the perception of the trill, even if it is not present.

The results obtained here are limited by the sample size, by the lack of comparable data available for post-alveolar sibilants and, probably, by the use of fieldwork data. In order to overcome some of these limitations, this study is now being replicated for the palatals and post-alveolar sibilants produced by these same speakers.

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