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Gestural lenition of rhotics captures variation in Brazilian Portuguese

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Abstract

The goal of this study is to examine the rhotics in Brazilian Portuguese (BP), /ɾ,ʁ/ and the 'archetypal' coda /R/, to determine if: (1) they can be characterized as a coordination of the tongue dorsum and tongue body or tip and (2) manipulation of the gestural settings accounts for rhotic allophony in BP.

Six native speakers of BP participated in an ultrasound experiment and produced target phonemes in #CV, VCV, and VC# environments with the vowels /i, e, a, o/. Tongue contours for the rhotics were compared using Smoothing Spline ANOVAs. /ɾ, ʁ/ were produced with a tongue body and dorsum gesture, while /ɾ/ also had an apical gesture. Archetypal /R/ was realized variably, as any of [ɾ, ɻ, ɹ, χ].

BP rhotics can be described as the coordination of a tongue dorsum and a tongue body or tip gesture. 'Archetypal' /R/ is posited to be /ɾ/. Allophony between /ɾ/ and [ɻ, ɹ, χ] is due to tongue tip lenition. Allophony between /ʁ/ and [h] is due to weakening of the tongue dorsum and body gestures. This analysis suggests synchronic and diachronic changes of rhotics result from lenition. It also captures the rarity of diachronic changes from uvulars to alveolars.

Index Terms: rhotics, rhotic representation, allophonic variation, articulatory phonology, ultrasound, Brazilian Portuguese

1. Introduction

Rhotics have presented themselves as a problem class over the past few decades of linguistic research. Phoneticians have had difficulty in pinning down any consistent acoustic or articulatory characteristics [1]. Rhotics have also caused adversity for feature-based theories of phonology because their phonological distribution and behaviour has been difficult to capture [2].

However, recent articulatory studies have begun to capture consistent articulatory characteristics associated with rhotics. Narayanan et al. [3] performed an MRI study of Tamil and found consistency in articulation between the three rhotics, /r r̠ ɻ/. Each rhotic had a lateral bracing in the palatal region, creating a concave shape. As a result, there was a pitted [3, p. 1996] cavity in the tongue body.

Delattre [4] and Recasens & Espinosa [5] both assert that rhotics are characterized by a tongue dorsum gesture creating a constriction in the pharyngeal region. Proctor's [6] observations, based on ultrasound evidence, led him to posit that rhotics are the complex coordination of the tongue dorsum and the tongue tip. This was used to explain liquid metathesis as a product of a phase shift between the intergestural timing of vowel-liquid sequences. Proctor [6] also suggested the need to coordinate the tongue dorsum gesture characteristic of rhotics with the tongue dorsum gesture present in vowels results in the cross-linguistic pattern of rhotics appearing adjacent to vocoids.

Howson [7] built on the approach put forth by Proctor [6] based on acoustic evidence of alveolar and uvular rhotics in Upper Sorbian by suggesting that a generalized gestural representation of rhotics could be described as a vocalic tongue dorsum gesture coordinated by a consonantal tongue gesture. In the case of alveolars, this gesture is produced with the tongue tip, but for uvulars it is produced with the tongue body. Howson [7] also suggested that the tongue dorsum gesture must be coordinated with the surrounding vocoids and results in the cross-linguistic tendency for rhotics to be adjacent to vocoids.

1.1. Brazilian Portuguese

Brazilian Portuguese has two rhotics, /ɾ ʁ/, (*caro* [kaɾʊ] 'expensive;' *carro* [kaʁʊ] 'car') which contrast intervocalically. /ʁ/ is found in word-initially and an 'archiphoneme' /R/ phoneme is found in coda positions, although it often emerges as a tap, it is subject to regional variation [8]. The underlying representation for the archiphoneme is unclear due to the significant variation by region. Both rhotics are also well known for having significant variation depending on both prosodic [9, 10, 11] and positional [8, 12, 13] conditions. For example, when word-initial /ʁ/ is under conditions where the onset is strongly stressed, the realization can be [r]. Interestingly, Silva [10] notes this effect is gradient, with [ʁ] and [r] representing two opposite sides of the continuum. The more stress placed on the onset, the less frication emerges and under weaker stressed conditions a trill fricative, [r̝], is realized. Word-finally, there is allophonic variation between [ɾ] and [ɹ ɽ χ] depending on both the speaker and the region [13, 14].

1.2. Hypotheses

Previous work has examined approximant rhotics at multiple places of articulation but incorporating fricatives into the gestural model of rhotics has not been done. Brazilian Portuguese has rich rhotic allophony, so it provides a good testing ground for previous gestural models and their ability to account for phonological alternations.

Based on previous research [4, 5, 6], it is hypothesized that the alveolar tap /ɾ/ will be composed of a vocalic tongue dorsum gesture coordinated with a tongue body and tongue tip gesture. The variability between [ɾ] and [ɹ ɽ χ] word-finally are proposed to be the result of lenition of the tongue tip gesture in word-final position. Lenition of this kind is in the word-final position has been previously noted by many researchers [15, 16, 17, 18] to account for liquid vocalization, debuccalization, deletion, and spirantization.

The uvular fricative /ʁ/ is hypothesized to be the composition of a tongue dorsum gesture coordinated with a

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tongue body gesture. The alternation between /ʁ/ in onset positions and [h] intervocalically is proposed to also be the result of lenition. Onset strengthening [19, 20, 21, 22] of /ʁ/ is expected to result in the consistent realization of [ʁ] in word-initial position. However, lenition resulting from the intervocalic position due to increased phonetic pressure from the flanking vocoids is anticipated to cause [h] to surface.

2. Methods

2.1. Participants

Six native speakers of Brazilian Portuguese were recruited from the student community in Toronto. Participants were all undergraduate students aged 18-24 and were all originally born in São Paulo, Brazil. All participants provided informed consent and had no self-reported speaking or hearing problems.

2.2. Procedure

Data was recorded using an Ultrasonix ultrasound (60 fps) with audio and video synchronization through AAA software [23]. Participants wore headgear to hold the transducer in a stable position. Participants read a randomized wordlist 8 times (12 conditions x 2 phonemes x 8 repetitions x 6 speakers + 6 conditions x 2 phonemes x 8 repetitions x 6 speakers = a total of 1,728 tokens, 288 tokens per speaker).

Target stimuli were the two Brazilian Portuguese rhotics, /ɾ ʁ/; two stops /t k/ were included as controls. Stimuli were produced in the word-initial, intervocalic, and word-final position with each of the vowels [i e a o]. /ɾ/ does not appear word-initially and /ʁ/ does not appear word-finally, so these tokens are absent from the dataset. Tokens were embedded in a carrier phrase “diga *target* para si mesmo” [say target for yourself] to facilitate natural productions. Table 1 summarizes the stimuli for /ɾ ʁ/ and ‘archiphoneme’ /R/.

Table 1. Rhotic stimuli, target phonemes in bold.

/ʁ/		/ɾ/ and ‘archiphoneme’ /R/	
***r**ato*	‘mouse’	*a**r**ado*	‘plow’
***r**eto*	‘straight’	*e**r**eto*	‘upright’
***r**oto*	‘broken’	*ou**r**o*	‘gold’
***r**ito*	‘ritual’	*i**r**isa*	‘to shade’
*ba**rr**a*	‘bar’	*da**r***	‘to give’
*be**rr**e*	‘scream’	*de**r***	‘to give fut. subjunctive’
*bo**rr**o*	‘(I) blot’	*do**r***	‘pain’
*i**rr**iga*	‘irrigate’	*vi**r***	‘to come’

2.3. Analysis

Analysis was done with a smoothing spline (SS)ANOVA [24, 25]. The point of maximum constriction was determined through acoustic and visual inspection and the tongue contours were traced for each of the environmental and positional conditions. Comparisons were made across word-positions and across phonetic environment. Plots were generated using R [26].

3. Results

3.1. SSANOVA Results

The results for BP5 will be presented and discussed followed by general cross-speaker results. This section is organized such that the control phonemes /t k/ are presented first followed by /ɾ ʁ/.

The SSANOVA results for /t/ showed a variable tongue dorsum position, most noticeable in the intervocalic position (Figure 1). /o/ produced the most tongue dorsum retraction, while /i e/ produced tongue dorsum fronting and tongue body raising, consistent with palatalization. In the word-final position, /t/ was consistently palatalized in the environments /i e a/. This was visible due to tongue body raising and fronting and fronting of the tongue dorsum before /i e a/. /o/ exhibited a similar degree of retraction with the other word-positions, but the tongue blade was raised more, for a more laminal articulation.

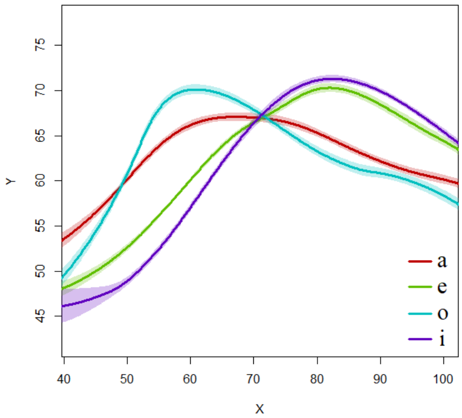

Figure 1: *Tongue contours for /t/ in intervocalic position for each vocalic environment*.

/k/ exhibited a similar pattern to /t/: The position of the tongue dorsum was variable by vocalic environment. /o/ produced the most retraction and /i e/ produced the most advancement (Figure 2). The effects were stronger in the intervocalic position but were still present in the word-initial position. In the word-final position, there was significant fronting for all phonetic environments. /o/ was more retracted than the other environments but was more fronted than /o/ in the other word-positions. /k/ in the /i e a/ environments was realized with fronting, consistent with palatalization.

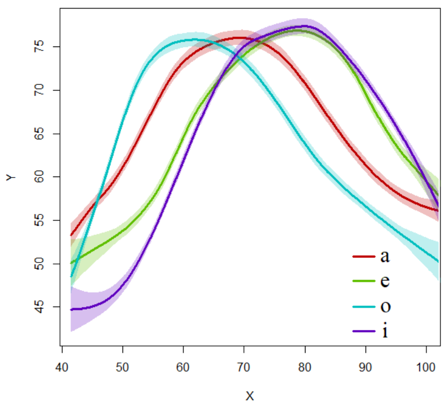

Figure 2: *Tongue contours for /k/ in the intervocalic position for each environment*.

The results for /ɾ/ showed less variability for the tongue dorsum in the intervocalic position. There was more retraction in the /o/ environment and more advancement in the /i/ environment, but there was no significant difference between the /e a/ environments (Figure 3). In the word-final position, 'archiphoneme' /ʁ/ was realized as an approximant /ɹ/ with a bunched articulation (Figure 4). The tongue dorsum was invariable across all environments except a slight, but significant, advancement in the /i/ environment.

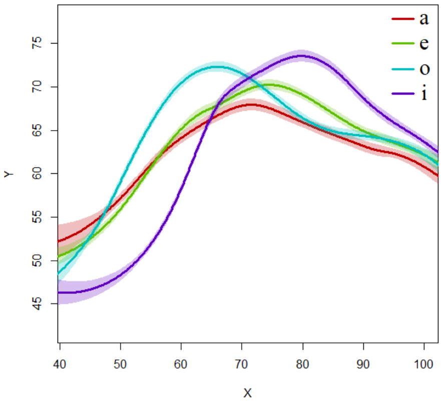

Figure 3: *Tongue contours for /ɾ/ in the intervocalic position for each environment.*

The uvular rhotic, /ʁ/, had a relatively invariable tongue dorsum and tongue body. However, there was a slight advancement of the tongue dorsum/body in the /i/ environment and a slight retraction in the /o/ environment (Figure 5). The intervocalic position showed a great deal of variability in the tongue dorsum, body, and tip/blade. The results showed that the tongue contours for /ʁ/ more closely resembled their phonetic environments, suggesting a placeless articulation (Figure 6).

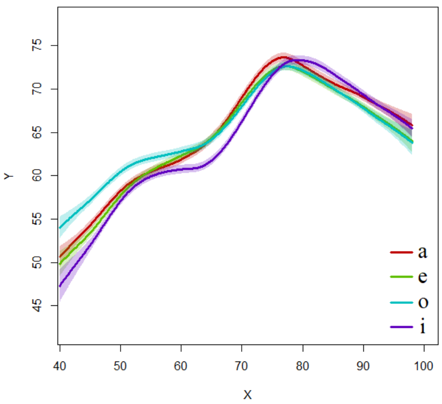

Figure 4: *Tongue contours for /R/ in the word-final position for each environment.*

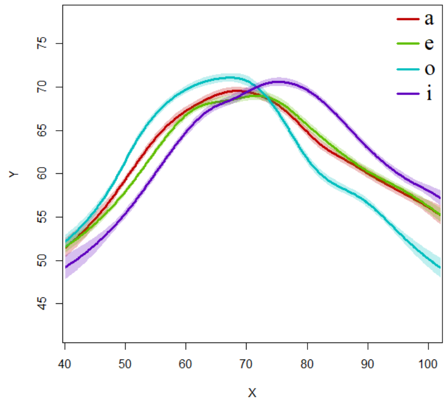

Figure 5: *Tongue contours for /ʁ/ in the word-initial position for each environment.*

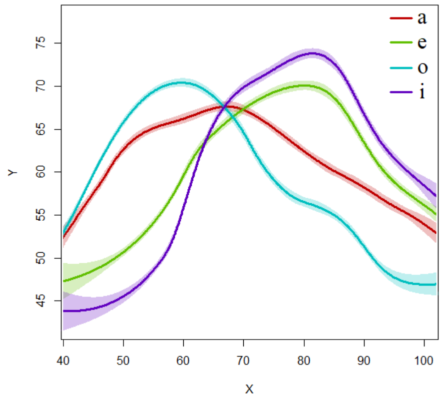

Figure 6: *Tongue contours for /ʁ/ in the intervocalic position for each environment.*

The overall results showed that for all speakers /t/ was produced with the tongue tip/blade, but the dorsum and body were highly susceptible to phonetic environment. /o/ environment resulted in the greatest retraction, while /i e/ produced articulations more consistent with allophonic palatalization (i.e. /t/ was realized as [ʧ]). In word-final position, all speakers produced palatalized articulation for each phonetic environment.

/k/ was primarily produced with a closure made with the posterior region of the tongue body. It was highly susceptible to phonetic environment and like /t/ exhibited the most tongue dorsum retraction /o/ and the most tongue dorsum advancement in the /i e/ environments. In word-final position, /k/ was also fronted, irrespective of phonetic environment.

/ɾ/ had little variability in the intervocalic position across speakers: there was a slight retraction in the /o/ environment and slight advancement in the /i/ environment. However, in the word-final position, there was a great deal of speaker variation for 'archiphoneme' /R/. Interspeaker variation included [ɾ r ɹ ɻ χ]. Table 2 summarizes the speaker differences for /ɾ/ in word-final position. For all speakers, /ʁ/ exhibited the same pattern as BP5: small amounts of variability in word-initial position and placeless, [h]-like articulations intervocalically.

Table 2: Realizations of /R/ for each speaker.

	/R/
BP1	[ɹ]
BP2	[ɾ]
BP3	[χ]
BP4	[ɾ]
BP5	[ɹ]
BP6	[ɾ]

Comparison of the word-initial /ʁ/ and word-final /ɾ/ for BP2 and BP4 revealed a similarity in the tongue shape for the tongue dorsum and body (Figure 7). The primary difference between the articulation of /ʁ ɾ/ is in the presence or absence of a tongue tip gesture.

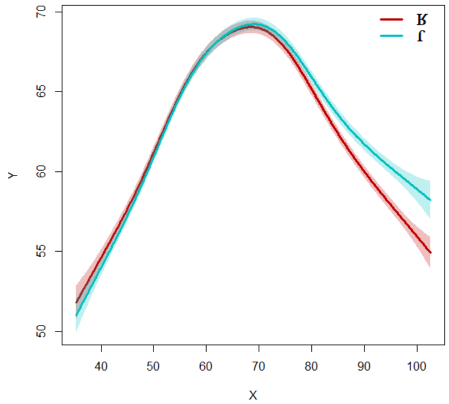

Figure 7: *Comparison of /ʁ/ in word-initial position and /R/ in word-final position*.

4. Discussion

The results for the tap suggest rhotics are composed of the coordination of a tongue dorsum and tongue tip gesture. The resistance of the tongue dorsum to phonetic environment suggests that it is an active phonological gesture. The presence of the tongue dorsum gesture is evident in two different ways: (1) consistent tongue dorsum retraction and high coarticulatory resistance; and (2) lenition of the tongue tip gesture (BP3's word final articulation of /ɾ/) still yields a consistent tongue dorsum gesture. The degree of resistance of the tongue body and tongue dorsum is comparable across speakers and suggests that the tongue body is also active, consistent with the findings in Proctor [6]. However, the results taken together suggest that tongue tip rhotics may be more complex than Proctor [6] suggests: the involvement of the tongue tip, body, and dorsum, provide a more complete picture of rhotic articulation. Figure 8 illustrates the gestural representation for the tap in Brazilian Portuguese.

/ɾ/
nar{TT(alv)}
| 0°
wide{TB(uv-phar)}
| 0°
wide{TD(phar)}

Figure 8: *Gestural representation for /ɾ/.*

The allophony observed in Brazilian Portuguese is also straightforwardly accounted for by a process of word-final lenition. Word-final lenition affects the realization of numerous phonemes [16, 17, 18] and in the case of Brazilian Portuguese, a weakened tongue tip gesture accounts for the approximant realizations [ɻ ɹ]. The process of lenition results in the aperture setting for the tongue tip to be changed from narrow to wide. This results in an approximant articulation instead of a tap. The word-final [χ] is also explained by lenition of the tongue tip gesture, resulting in a loss of the tongue tip as an articulator.

The results also suggest a similar gestural representation for /ʁ/ as /ɾ/. /ʁ/ is composed of the coordination of a tongue body gesture and a tongue dorsum gesture. This is best evidenced in the word-initial position: high coarticulatory resistance of the tongue body and the tongue dorsum suggest active gestures.

/ʁ/
wide{TB(uv-phar)}
| 0°
wide{TD(phar)}

Figure 8: *Gestural representation for /ʁ/.*

The allophonic variation with [h] in intervocalic position is also explained by lenition. Both the tongue body and tongue dorsum gesture undergo lenition, resulting in a placeless articulation. This was observed across all speakers where the articulation of /ʁ/ closely resembled the surrounding phonetic environment.

Finally, the results indicate that a process of lenition occurred through the historical changes in Portuguese. Lenition of the singleton and geminate trills (e.g. *ferum* – *ferrum*) in Latin lead to the original tap – trill contrast [27]. The data presented in this study suggest that the change from alveolar trill to uvular trill occurred because of lenition of the tongue tip gesture. This underwent further lenition of the tongue body gesture to arrive at the present day uvular fricative. The results suggesting that 'archiphoneme' /R/ is underlyingly a tap is also consistent with Noll's [28] observation that dialects that maintain the tap in coda position are an archaism.

5. Conclusion

The data suggests that tongue tip trills are complex segments composed of a tongue dorsum and body gesture coordinated with a tongue tip gesture, while uvular rhotics are composed of simply a tongue dorsum and tongue body gesture. The data also provided evidence that manipulation of the gestural settings results in the various synchronic and diachronic changes in Brazilian Portuguese. Another interesting implication of the data is an explanation for the cross-linguistic tendency for sound change from alveolar to uvular rhotics, but rarely in the other direction [2]. The simple reason for this is that the alveolar gesture undergoes lenition to arrive at the uvular. In order for the uvular to change to an alveolar, fortition of an alveolar gesture is required, which is a far less common historical sound change [28].

6. Acknowledgements

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