ALVEOLAR-TO-RHOTIC COARTICULATION IN NORTH AMERICAN ENGLISH: A PRELIMINARY EPG STUDY

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ABSTRACT

This paper reports results of an electropalatographic (EPG) study of alveolar-to-rhotic coarticulation in North American English. Data with alveolars /d/ and /n/ occurring in various rhotic contexts were collected from a single female speaker. The results showed a continuum of backing of the primary constriction from alveolar to post-alveolar or retroflex as a function of the absence or presence of one or more rhotic segments in the word and their proximity to the alveolar. These findings are interpreted as coarticulation of alveolars to the more constrained rhotic approximant and rhotacized vowels, and to different degrees of overlap of alveolar and rhotic gestures. The results, albeit preliminary, provide evidence for retroflexed allophones of English alveolars and point to articulatory sources of phonological patterns of retroflexion.

Keywords: coarticulation, rhotic, alveolar, gestural overlap, electropalatography, English

1. INTRODUCTION

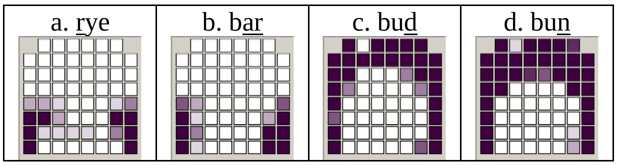
The North American English rhotic approximant /ɹ/ is known for its articulatory complexity (e.g. [1, 4]). The production of this consonant is characterized by the primary constriction in the oral cavity and two secondary constrictions – in the pharyngeal cavity and at the lips. The primary constriction is formed by the middle part of the tongue raised towards the hard palate, which can be achieved either by raising the tongue tip up (the 'retroflex' /ɹ/) or 'bunching' the tongue body (the 'bunched' /ɹ/). Given its articulatory complexity, /ɹ/ is highly resistant to coarticulation to neighboring consonants and vowels [2]. Less is known, however, how the rhotic approximant or rhotacized vowels affect the articulation of neighboring segments. Descriptive phonetic accounts of North American English state that non-initial alveolars /t/, /d/, and /n/ are somewhat 'retroflexed' when adjacent to rhotics. For example, Rogers [7] transcribes the words with post-rhotic alveolars in words *hurt* and *card* as [hɚʈ] and [kʰɑ˞ɖ] (pp. 293-294). To what extent the alveolars actually change their primary place of articulation and/or acquire secondary tongue raising in this context has not been systematically studied, at least for North American English. Note that the process of post-rhotic retroflexion is related to, but not identical to, the allophonic variation affecting syllable-initial alveolars before /ɹ/. Thus in North American and some other varieties of English, /t/ and /d/ are not only retracted but also affricated (e.g. [ʈʂʷɹi] *tree* and [ɖʐʷɹim] *dream*), while /s/ is 'palatalized' to [ʃ] ([ʃʈɹit] *street*) [6, 7, 8]. The pre-rhotic changes seem to go beyond coarticulation proper and are often sociolinguistically conditioned. These changes are not the focus of the current study.

The goal of this paper is to conduct a preliminary investigation of the production of word-final and word-medial alveolars /d/ and /n/ preceded and followed by rhotic approximants and/or rhotacized vowels. Assuming that coarticulation results from temporal overlap of articulatory gestures [3], we would expect that the degree of alveolar-to-rhotic coarticulation is greater when the alveolar is overlapped by one or more rhotic gestures. For example, the model predicts a greater coarticulatory effect for /d/ in *hard* [hɑ˞d] (an overlapping rhotic gesture) than in *broad* [bɹɑd] (a non-overlapping rhotic gesture), and even a greater effect in *harder* [hɑ˞dɚ] (two overlapping rhotic gestures).

2. METHOD

To investigate alveolar-to-rhotic coarticulation, simultaneous EPG and acoustic data were collected from a female speaker of Canadian English from Southern Ontario (speaking a rhotic dialect similar in relevant respects to General American [7]). A prior examination of rhotics and other consonants produced by this speaker showed the expected lateral constriction in the palatal region – the last 4 rows of the artificial palate, as seen in Fig. 1a,b. This constriction had somewhat greater central contact for syllable-initial /ɹ/ than for the same consonant syllable-finally. In contrast, /d/ and /n/ showed a complete closure in the alveolar region– the first 2-3 rows of the palate, as seen in Fig. 1c,d. (The second electrode in the first row of the speaker's palate shows no contact due to malfunction; cf. Fig. 2.)

Figure 1: Averaged linguopalatal contact profiles for /ɹ/ (as [ɹ] and [ɑ˞]), [d], and [n] taken at the point of maximum constriction, with shading indicating the degree of contact (6 tokens produced in isolation).



The materials consisted of 42 words with alveolars /d/ and /n/ preceded by 3 different vowels and embedded in 7 different 'rhotic contexts' (see Table 1). These contexts were designed to differ in the absence or presence of the rhotic gesture(s), their magnitude, and the degree of overlap with the alveolar gesture, and were as follows: no rhotic within a word (context 1), a preceding non-adjacent rhotic approximant (context 2), a preceding adjacent rhotacized vowel (context 3), a following adjacent rhotacized vowel (context 4), a combination of a preceding non-adjacent rhotic approximant and a following adjacent rhotacized vowel (context 5), a combination of a preceding and following adjacent rhotacized vowel (context 6), and combination of a preceding adjacent rhotacized vowel and a following rhotic approximant optionally occurring across a (plain or rhotacized) schwa (context 7). The voiced /d/ rather voiceless /t/ was chosen as one of the target consonants, as it is less prone to flapping in the intervocalic context. When finding words with /d/ in a particular context was not possible, corresponding words with /t/ were used instead (*artery* and *rotor*).

To determine the extent of rhotic gestures and their 'pure' coarticulatory effects on neighboring consonants, words with the labial /m/ occurring in the same 7 contexts were also included: *bomb*, *from*, *farm*, *bomber*, *Frommer's*, *farmer*, and *armoury*. All the stimuli (with alveolars and labials) were presented in a carrier phrase *Say __ again* and read 12 times at a comfortable speaking rate. Overall, this resulted in 588 tokens used for analysis (49 items x 12 repetitions).

Table 1: Stimuli used in the study (ɹ̩ = a rhotacized vowel).

C	Context	[ɑ]/[ɑ˞]	[ow]/[o˞]	[ʌ]/[ɚ]
/d/	1. no ɹ	pod	mode	bud
	2. ɹV_	broad	road	rudd
	3. ɹ̩_	hard	board	bird
	4. _ɹ̩	fodder	odour	udder
	5. ɹV_ɹ̩	broader	rotor	rudder
	6. ɹ̩_ɹ̩	harder	border	murder
	7. ɹ̩_(V)ɹ	artery	corduroy	murderer
/n/	1. no ɹ	dawn	cone	bun
	2. ɹV_	prawn	prone	run
	3. ɹ̩_	barn	corn	burn
	4. _ɹ̩	honour	owner	gunner
	5. ɹV_ɹ̩	Bronner	proner	runner
	6. ɹ̩_ɹ̩	garner	corner	burner
	7. ɹ̩_(V)ɹ	garnering	cornering	ternary

An artificial palate with 62 electrodes was custom-made for the participant and articulatory data were collected using a WinEPG system [11] with a sampling rate of 100 Hz. Measurements of the tongue-palate contract were made for the target alveolars at the point of maximum contact, and for the control /m/ at the midpoint during its acoustically defined closure. These measurements were converted to two indices: (i) Contact Anteriority at the alveolar region (CAa), calculated as a weighted sum of electrode values in the first 4 rows of the palate, and Quotient of electrode activation in the palatal region (Qp), the last 4 rows of the palate (see [5]). The two measures were used to capture the relative front/back position of the tongue tip/blade constriction and the degree of tongue body raising, respectively. CAa was expected to be the highest in the no-rhotic context and the lowest in the contexts with two adjacent rhotics. Qp was expected to show the reverse.

3. RESULTS

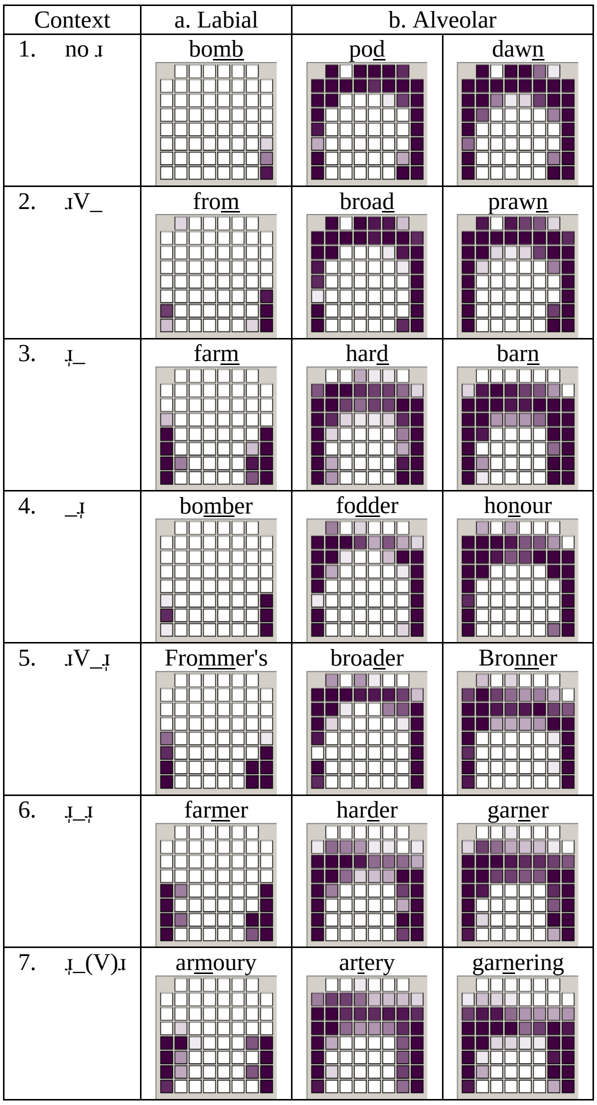
The results are first presented for the word set with labials, as these allow us to verify predictions about the rhotic gesture extent and overlap. This is followed by the results for the main data set – the words with target alveolars.

3.1. Rhotics and labials

An examination of the words with labials (see Fig. 2a) showed an increase in the palatal contact during /m/ from the first (*bomb*) to the last context (*armoury*). Overall more contact was observed when the rhotic belonged to an adjacent segment than to a non-adjacent one, as well as when it preceded rather than followed /m/ (e.g. *farm* >

bomber > *from*). Greater palatal contact was also observed in words with two rhotics compared to those with a single rhotic (*Frommer's* > *bomber*, *farmer* > *farm*). These observations were reflected in differences in Qp values across the contexts. The results thus confirmed the predicted patterns of overlap of rhotic gestures with those of other, adjacent and non-adjacent, consonants. Assuming that the same patterns of overlap apply in words with alveolars, the latter consonants were expected to coarticulate with rhotics, gradiently changing their primary constriction from alveolar to post-alveolar/retroflex and acquiring a secondary tongue body raising.

Figure 2: Averaged linguopalatal contact profiles for (a) the labial /m/ and (b) the alveolar /d/ and /n/ (based on 12 tokens).



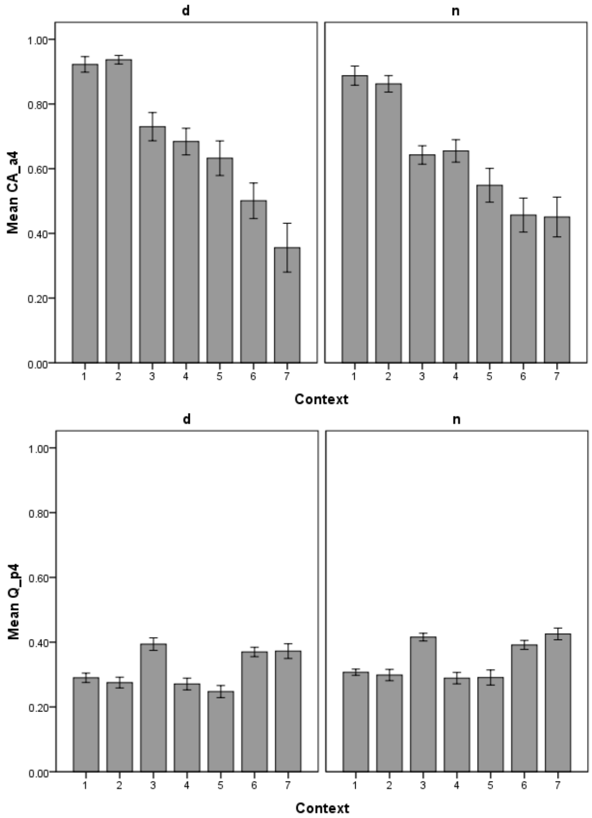
Context	a. Labial	b. Alveolar	
1. no ɹ	bomb	pod	dawn
2. ɹV_	from	broad	prawn
3. ɹ̩_	farm	hard	barn
4. _ɹ̩	bomber	fodder	honour
5. ɹV_ɹ̩	Frommer's	broader	Bronner
6. ɹ̩_ɹ̩	farmer	harder	garner
7. ɹ̩_(V)ɹ	armoury	artery	garnering

3.2. Rhotics and alveolars

The results showed that the constriction location of alveolars shifted considerably further back under the influence of adjacent rhotics, and particularly in words with two rhotics. As seen in Fig. 2b, /d/ and /n/ were produced in contexts 1 and 2 with a closure in the first two rows of the palate, that is in the alveolar region (e.g. *pod* and *broad*). The closure for the same consonants was further back, in rows 2 and 3 when produced next to a single rhotic (contexts 3-5, e.g. *hard*, *fodder*, and *broader*). The closure was even further back, often in rows 3 and 4, in words with two adjacent rhotics (contexts 6-7, e.g. *harder* and *artery*). The somewhat greater effect in context 7 can be attributed to the following syllable-initial rhotic approximant, which is more constricted than the rhotacized vowel (see Fig. 1a,b). Note also the greater palatal contact for alveolars immediately preceded by rhotacized vowels, than those followed by such vowels (e.g. *hard* vs. *fodder*). These differences are indicative of greater overlap of rhotic and alveolar gestures in the former context, consistent with the findings for labials presented in the previous section. Of interest is also some deocclusivization of the alveolars in contexts 4-7 (and especially in 6 and 7). This can be attributed to rhotic coraticulation, as well as the more general tendency to alveolar flapping in this intervocalic context.

Means and standard deviations for the entire alveolar data set are presented in Fig. 3, separately for the CAa and Qp measures. Pair-wise comparisons of the contexts confirmed the the observations stated above. CAa was significantly lower in contexts with at least one adjacent rhotic (contexts 3-7) compared to those with no rhotic or a non-adjacent rhotic (1-2) ($p<.001$). Within the former group, CAa was significantly lower in words with two rhotics (5-7) compared to those with a single rhotic (3, 4) ($p<.001$). Qp was significantly higher after an adjacent rhotic (3, 6, 7) than in any other context ($p<.001$). The nasal /n/ showed lower CAa and higher Qp in all of the contexts, indicative of an overall less anterior constriction with greater palatal contact compared to /d/ (e.g. *bud* vs. *bun*). Among the vowel contexts, alveolars tended to be produced with a less anterior constriction (lower CAa) after the mid back rounded vowel /o/, compared to the other two vowels (e.g. *mode* vs. *pod* and *bud*).

Figure 3: Mean values for Contact Anteriority (alveolar) and Quotient of palatal contact by consonant and rhotic context.



4. DISCUSSION AND CONCLUSION

An examination of alveolars /d/ and /n/ produced by a speaker of Canadian English has revealed clear coarticulatory influences of neighboring rhotics – the highly constrained rhotic approximants and rhotacized vowels (cf. [2]). The rhotic coarticultory effects were manifested in the gradient change of the primary place of articulation of /d/ and /n/ from alveolar towards post-alveolar or retroflex, and an addition of a secondary rhotic-like tongue body raising articulation. The degree of coarticulatory effects depended strongly on the extent of overlap of alveolar and rhotic gestures, supporting the co-production model of coarticulation [3]. In other words, the constriction made by the tongue tip gesture for the alveolar is retracted when it is substantially overlapped by the rhotic gesture (e.g. *hard* [hɑ˞d]), as opposed to the context where the overlap is minimal (*broad* [bɹɑd]) or absent (*pod* [pɑd]). The retraction of the tongue tip constriction is even greater when the tongue tip gesture is overlapped by two rhotic gestures (e.g. *harder* [hɑ˞dɚ] or *garnering* [gɑ˞n(ɚ)ɹiŋ]). Interestingly, in such contexts the target consonants seem to approach in their articulation to proto-typical retroflex consonants, as, for example, in Norwegian and Arrernte [9, 10]. This confirms the previous impressionistic descriptions of North American English alveolar allophones after rhotics as 'retroflexed' [7]. To what extent the results of this preliminary study are representative of North American English is a question requiring further investigation.

5. REFERENCES

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