/ʁ/ LENGTHENING CONSONANTS CREATED EQUAL IN QUÉBEC FRENCH?

Jeffrey Lamontagne[1], Kaitlyn Owens[1], Dav Rosychuk[2], and Anne-José Villeneuve[2]
[1]Indiana University – Bloomington and [2]University of Alberta – Saint-Jean Campus

1.   Introduction

Cross-linguistically, rhotics are a phonetically heterogeneous and variable category, with both places and manners of articulation varying over time and between regions (e.g., Ladefoged and Maddieson 1996, Chabot 2019). Consistent with this pattern, the rhotic in western varieties of Québec French has recently been undergoing a change whereby its former realisation as an apical flap ([ɾ]) has increasingly been replaced by a uvular fricative or trill ([ʁ ʀ χ]; e.g., Clermont and Cedergren 1979, Sankoff and Blondeau 2007, Côté and Saint-Amant 2012, Saint-Amant Lamy 2022).[1] This change has been described as a change from above (i.e., conscious) acquired through contact with other dialects of French who adopted the Parisian French feature earlier (Trudgill 1974) and it is accompanied by social evaluations; the uvular variants are associated with higher socio-economic classes, with urban speakers, and with younger speakers (e.g., Blondeau et al. 2002). The phonetic and phonological consequences of this change from apical to uvular, however, would be expected to be relatively large: while the rhotic being represented as a fricative would render it more phonologically similar to other phonemes that have overlapping phonological behaviour (notably lengthening, as described below), the phonetic precursors arising from this large shift in place of articulation would likely engender changes in surrounding sounds through coarticulation.

The current study investigates the differences in phonological and phonetic behaviours of the rhotic as compared to the other members of the phonologically active class of lengthening consonants in French (/v z ʒ/; e.g., Walker 1984) to probe the extent to which the rhotic patterns with its phonologically active class (lengthening consonants) or distinctly (e.g., due to differences in phonetic precursors).[2] Two phonological test cases that unify these consonants were selected for analysis: high-vowel laxing and

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[1] We use the term Québec French rather than alternative labels (Canadian French, Laurentian French) because the speakers under examination are all from the province of Québec. With respect to transcription norms used throughout this paper, we use the common convention for French to represent the rhotic as /ʁ/ in phonemic transcriptions without claim as to any given speaker's phonetic realisation (which may be variable) and use phonemic and phonetic transcriptions representative of the dialect under examination (or, in section 2.2, the categories submitted for forced alignment).

[2] We note that /vʁ/ also triggers lengthening of the final-syllable vowel when in the coda and will therefore be included in the analysis. This apparent exception is the only one in which /ʁ/ is in second position within a cluster formed only of consonants that would trigger lengthening as the coda and, historically, the only such cluster of rising sonority.

diphthongisation.[3] As illustrated in (1), the first process, laxing, is one that targets non-lengthened high vowels in Québec French such that they surface as tense in final open syllables but as lax in final closed syllables surface (e.g., Dumas 1983, Poliquin 2006, Côté 2012). Phonologically lengthened high vowels, however, variably surface as tense or lax, with authors offering differing descriptions due perhaps to sociolinguistic variation or regional differences (for discussion, see Burness et al. 2022). Given that uvular rhotics require a backed and potentially lowered tongue position and that this could induce the percept of laxing (cf. ultrasound data from Dalton 2011), we expect that the rhotic will trigger more frequent application of high-vowel laxing.

(1)   High-vowel laxing in Québec French (final syllables)
       [ekʁi]   *écrit*   'written.MASC'   [ekʁɪt]   *écrite*   'written.FEM'
       [ʁy]   *rue*   'road'   [ʁʏm]   *rhume*   'common cold'
       [pu]   *pouls*   'pulse'   [pʊl]   *poule*   'hen'

Our second process, diphthongisation, is a well-known phenomenon in Québec French whereby phonologically long vowels break into a nucleus and offglide, the quality of which is determined by the phoneme undergoing the process (see e.g., Dumas 1983; Walker 1984; Côté 2010, 2012). While a wide variety of phonemes in Québec French are eligible for diphthongisation due to phonemic or derived length (see Lamontagne and Goad 2019), we focus on high vowels in the current study to restrict the number of social and phonological constraints that may be constraining realisations and to maximise the potential to see coarticulation-induced differences resulting from the tongue's back (and non-high) position for the production of the rhotic compared to the lingual lengthening codas. Authors differ in whether they describe high vowels as eligible for diphthongisation when lengthened by a lengthening coda (see Burness et al. 2022), but descriptions in the literature suggest that this may be a context where a distinction is traditionally found between rhotics, which would be more permissive of high-vowel diphthongisation, and other lengthening codas, which may disfavour the process more strongly. In the case of /i y u/, the off-glides are the corresponding glides found in the phonemic inventory of French /j ɥ w/ following a nucleus of matching backness and rounding but variably high or mid-high (cf. Dumas 1974; MacLaughlin 1987; Côté 2010; Sigouin and Arnaud 2014, 2015), which suggests relatively large acoustic ranges for the height of the nucleus and therefore a greater potential to find differences associated with coda type.

These two processes offer an optimal opportunity to establish whether (a) the rhotic patterns like other lengthening codas despite the shift in place and manner, and (b) whether these effects are comparable across the three vowel phonemes given that the coarticulatory constraints may be especially large for front vowels followed by the uvular rhotic. Our study leverages a combination of forced alignment to classify high-vowel

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[3] While both processes variably occur in non-final syllables, we focus on final syllables in the current study because both processes are most readily available – or categorical, in the case of laxing – in this context (e.g., Côté 2012).

tenseness on one hand and formant measurements to establish both the degree of diphthongisation and the quality of the nucleus on the other, using corpora of spontaneous televised speech. Our results demonstrate that, while the rhotic does show distinct patterning, some of those patterns can be ascribed to the coarticulatory pressures and degree of phonetic lengthening that it triggers. The results further demonstrate that both processes (laxing and diphthongisation) occur in relatively formal conversational contexts despite diphthongisation traditionally being associated with casual speech, some degree of stigma or negative sociolinguistic judgment when applied to other phonemes (e.g., Côté 2012).

2.   Methods

The current study investigates the phonological behaviour triggered by the French rhotic to probe the phonological consequences of recent changes in its realisation in certain varieties of Québec French from an alveolar flap to a uvular trill or fricative. In section 2.1, we introduce the corpora from which the data under analysis are drawn. In section 2.2, we then describe the expansion of a forced aligner's pronunciation dictionary to allow classification of high-vowel tenseness and the resulting forced alignment. Section 2.3 provides information on the acoustic measures submitted for analysis. Finally, in section 2.4, we explain the statistical analysis of the resulting data (both high-vowel tenseness and diphthongisation), with a focus on the predictors and the motivations for their inclusion in the current study.

2.1   Corpus

The current study exploits two corpora of spontaneous televised Québec French broadcasted through the Canadian Broadcasting Corporation's *Société Radio-Canada*. The first corpus draws from the television program *On prend toujours un train pour la vie* (henceforth *Un Train*), in which Québec public figures, generally members of the cultural or political elite (e.g., politicians, artists, businesspeople) discuss highly emotional aspects of their personal and professional lives. The second corpus is comprised of speech from the television program *Téléjournal Le Point* (henceforth *Le Point*), in which some of the same interviewees discuss more objective issues related to their role as public figures. Combining the two corpora, we obtain data from 26 speakers.[4]

2.2   Forced alignment and classification of tenseness

Forced alignment using the Montreal Forced Aligner (McAuliffe et al. 2017) served not only to generate TextGrids used for acoustic analysis (see section 2.3), but also to code high-vowel tenseness. To do so, the forced aligner was provided lexical transcriptions in

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[4] For a detailed description of the two corpora and a discussion of some of the sociolinguistic differences between *Un Train* and *Le Point*, see Villeneuve 2017.

which high vowels in final open syllables were categorically tense (i.e., [i y u]) and high vowels in final closed syllables without a lengthening coda were categorically lax (i.e., [ɪ ʏ ʊ]). This modification to the base ProsodyLab French pronunciation dictionary (Gorman et al. 2011) was implemented in Python and served to train the aligner on the acoustic characteristics of each high-vowel allophone under analysis (i.e., [i ɪ y ʏ u ʊ]). Crucially, the dictionary augmentation included generating two dictionary entries for words with high vowels in final-syllable lengthening contexts, meaning that the aligner determined whether the tense allophone or the lax allophone best matched the acoustic profile of the specific token (e.g., selecting between [p i ʁ] and [p ɪ ʁ] as the transcription for /piʁ/ *pire* 'worst'). Using forced alignment as a classifier for high-vowel tenseness in Québec French has been demonstrated to be highly effective compared to using formant values, with an accuracy rate of 87.56% and, in k-fold validation, reaching up to 91% accuracy (see Milne and Lamontagne 2016, Lamontagne 2020).

2.3   Acoustic measures

We used a Praat script to locate high vowels in lengthening contexts (high vowels in final syllables closed by /v z ʒ ʁ vʁ/) and to extract the values of the first two formants at 25% and 75% of each vowels' duration, as segmented through forced alignment. These values were converted to Barks to better reflect psychoacoustic frequency scaling (and therefore perceptual differences). The degree of diphthongisation was then calculated as the Euclidean Distance in formant space between the 25% and 75% measurement, following the Pythagorean Theorem as in (2):

(2) $$Euclidean\ Distance\ =\ \sqrt{(F1_{75\%} - F1_{25\%})^2 + (F2_{75\%} - F2_{25\%})^2}$$

In other words, our measure of diphthongisation conveys the length of the line in formant space (e.g., a vowel plot with F2 as the x-axis and F1 as the y-axis) that links the measurement at 25% of the vowel's duration to the measurement at 75% of the vowel's duration, reflecting how different those two values are. A larger Euclidean distance reflects a token with greater diphthongisation. We additionally retained the F1 (height) and F2 (backness) measurements at 25% of the vowel's duration as a measure of the quality of the nucleus to evaluate not only the degree of diphthongisation, given that the nucleus is expected to be especially salient to listeners given its greater duration and its increased distance from the lengthening consonant.

2.4   Statistical analysis

The current study draws on two types of data to probe the phonological behaviour of the Québec French rhotic: categorical (tenseness) and numerical (nucleus position, degree of diphthongisation). As such, we draw on logistic regression and linear regression respectively, though the models are largely otherwise identical in terms of the predictors included, and with respect to the inclusion of random intercepts that allow us to better

generalise from our individual speakers and lexical items. We therefore include as predictors the type of lengthening coda (two-level factor: /ʁ/ or another lengthening coda), the vowel phoneme (three-level factor: /i/, /y/, or /u/), and the interaction of these two factors in the model predicting tenseness.[5] In the models predicting F1 and F2 of the nucleus and the degree of diphthongisation, we included the total duration of the vowel in order to control for the increased amount of time for changes in articulation in vowels having longer durations, in addition to the type of lengthening coda and the vowel as classified during forced alignment (six-level factor: [i], [ɪ], [y], [ʏ], [u], [ʊ]).

We proposed the hypothesis that /ʁ/ will pattern distinctly from other lengthening consonants because the shift to a uvular realisation changes coarticulatory pressures despite that it has the potential to phonologically unify lengthening consonants under a single natural class (i.e., voiced fricatives). As such, we predict that laxing rates will be higher before /ʁ/ than before other lengthening consonants, that high vowels' nuclei will be lower and further back before /ʁ/ compared to before other lengthening consonants, and that there will consequently also be a larger degree of diphthongisation before /ʁ/ compared to before other lengthening consonants. We further predict that these differences will be largest for front vowels because they are articulatorily more distant from /ʁ/ than the back vowel /u/ is, and that, because of the formant-lowering effect of lip rounding (e.g., Kent and Rountrey 2020), /i/ will exhibit particularly large effects when compared to the rounded high vowels.

3.   Results

In this section, we present the results of our study investigating the phonological behaviours associated with the rhotic in Québec French. In total, we extracted 3,093 high vowels in final-syllable lengthening contexts. Section 3.1 describes the relationship between tenseness and both phoneme and coda category. In section 3.2, we describe how coda categories predict differences in height (F1) and backness (F2) of high vowels' nuclei. Finally, section 3.3 presents how the degree of diphthongisation is conditioned by coda category and vowel duration.

3.1   Categorical high-vowel laxing

A total of 1,286 of the extracted high vowels were classified as lax by the forced aligner (41.58%). As illustrated in Figure 1, the majority of lax tokens occur before /ʁ/ (1,107/1,186; 86.08%). As confirmed by our regression model (see Table 1), laxing is far less likely to occur before /v z ʒ/ than before /ʁ/ (β = -2.2433; p <0.0001).

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[5] Due to limited numbers of tokens for certain codas like /ʒ/ and asymmetries with respect to vowel-coda sequence frequencies, lengthening codas other than /ʁ/ were combined for the statistical analysis. We leave for future research the more nuanced differences among the non-rhotic lengthening consonants.
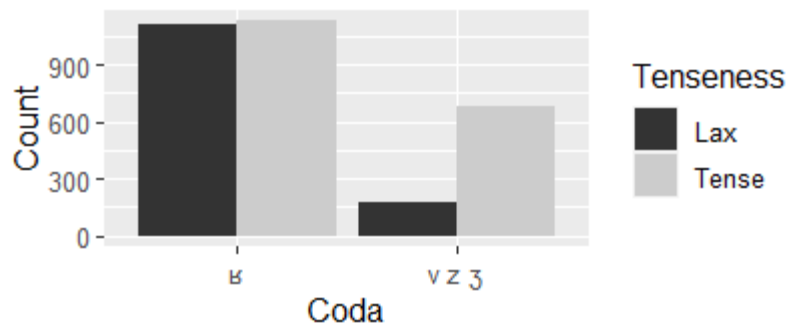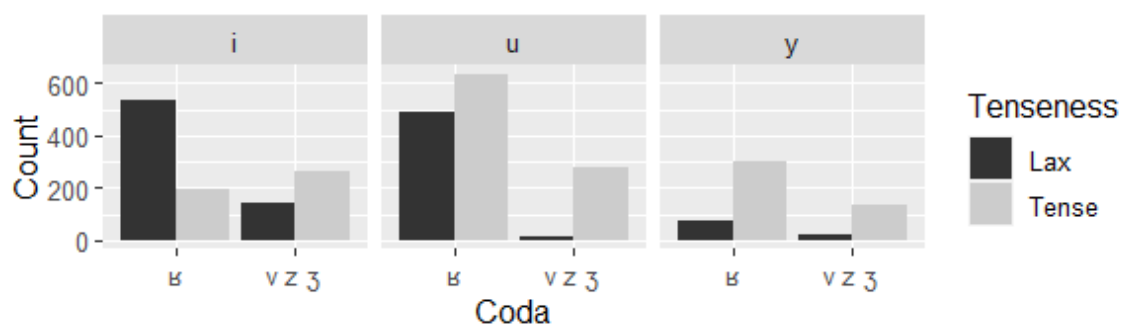
Figure 1. The effect of coda type on high-vowel tenseness.

Table 1. Mixed-effects logistic regression model output predicting tenseness.

Factor	Estimate	Standard error	z-value	p-value	
(Intercept)	1.325	0.248	5.336	< 0.0001	***
Coda /v z ʒ/	-2.243	0.359	-6.254	< 0.0001	***
Vowel /u/	-3.529	0.496	-7.111	< 0.0001	***
Vowel /y/	-2.097	0.478	-4.392	< 0.0001	***
Coda /v z ʒ/ : Vowel /u/	0.972	0.721	1.349	0.1775	
Coda /v z ʒ/ : Vowel /y/	1.518	0.868	1.749	0.0803	.

As shown in Figure 2, laxing also occurs more often for /i/ than for /y/ (β=-2.0972; p <0.0001) and /u/ (β=-3.5294; p <0.0001) when preceding the rhotic. The lack of significant and equally sizable coefficients for the interactions between coda type and vowel phoneme confirms that this greater laxing rate for unrounded than rounded phonemes is not limited to pre-rhotic contexts. Indeed, due to /i/'s propensity to lax with /ʁ/'s increased rate of triggering laxing makes laxing the majority variant for this combination. Overall, our results demonstrate that /ʁ/ is associated with laxing significantly more often than is the case for the other lengthening consonants. The following section examines the nucleus position to demonstrate that /ʁ/'s distinct patterning is not limited to the rate at which it triggers laxing.

Figure 2. The effect of coda category and vowel phoneme on high-vowel tenseness.

3.2 Nucleus position

Because high vowels' nuclei are expected to be affected by different coarticulatory pressures from the rhotic (that is now typically uvular) as compared to from other lengthening consonants, we ran mixed-effect linear regression models to predict vowel height (F1; Table 2) and backness (F2; Table 3) at 25% of the vowel's duration. As shown in Figure 3, [y] (β=57.67; p=0.0012), [u] (β=44.83; p=0.0018), and [ʊ] (β=77.31; p <0.0001) have lower nuclei (i.e., higher F1) before /ʁ/ compared to [i], with this being a marginally significant difference for [ɪ] (β=77.31; p <0.0001) as well.

In general, lax vowels are typically realised with lower tongue positions than their tense counterparts, consistent with trends described in the literature (see e.g., Burness et al. 2022). Further, nuclei for [ɪ] (β=-33.94; p=0.0433), [y] (β=-100.8; p=0.0020), and [u] (β=-56.71; p=0.0088) are higher before /v z ʒ/ than before /ʁ/ as compared to the same positional difference for /i/. Finally, longer vowels typically have significantly lower tongue positions for their nuclei than shorter ones (β=-0.2499; p<0.0001), which suggests that these effects are not solely due to undershoot (which would be most sizable in shorter tokens).

Table 2. Mixed-effects linear regression model output predicting vowel height (F1).

Factor	Estimate	Standard error	z-value	p-value
(Intercept)	447.30	13.69	32.680	< 0.0001 ***
Vowel duration (log)	-0.25	0.04	-6.324	< 0.0001 ***
Coda /v z ʒ/	4.50	13.90	0.324	0.7463
Vowel [ɪ]	20.06	10.35	1.938	0.0528 .
Vowel [u]	44.83	14.23	3.151	0.0018 **
Vowel [ʊ]	77.31	15.10	5.119	< 0.0001 ***
Vowel [y]	57.67	17.70	3.259	0.0012 **
Vowel [ʏ]	25.17	19.98	1.260	0.2081
Coda /v z ʒ/ : Vowel [ɪ]	-33.94	16.79	-2.022	0.0433 *
Coda /v z ʒ/ : Vowel [u]	-56.71	21.50	-2.638	0.0088 **
Coda /v z ʒ/ : Vowel [ʊ]	-34.72	37.54	-0.925	0.3552
Coda /v z ʒ/ : Vowel [y]	-100.80	32.15	-3.134	0.0020 **
Coda /v z ʒ/ : Vowel [ʏ]	-68.17	40.54	-1.682	0.0933 .

Table 3. Mixed-effects linear regression model output predicting vowel backness (F2).

Factor	Estimate	Standard error	t-value	p-value
(Intercept)	1931.00	34.28	59.330	< 0.0001 ***
Vowel duration (log)	-0.26	0.10	-2.619	0.0089 **
Coda /v z ʒ/	-48.29	37.93	-1.273	0.2034
Vowel [ɪ]	-55.21	25.03	-2.206	0.0274 *
Vowel [u]	-735.90	40.96	-17.970	< 0.0001 ***
Vowel [ʊ]	-620.90	43.12	-14.400	< 0.0001 ***
Vowel [y]	-251.80	49.47	-5.091	< 0.0001 ***
Vowel [ʏ]	-202.20	53.12	-3.806	0.0002 ***
Coda /v z ʒ/ : Vowel [ɪ]	136.30	41.54	3.281	0.0010 **
Coda /v z ʒ/ : Vowel [u]	118.60	62.24	1.905	0.0576 .
Coda /v z ʒ/ : Vowel [ʊ]	10.00	96.93	0.103	0.9179
Coda /v z ʒ/ : Vowel [y]	43.40	94.94	0.457	0.6478
Coda /v z ʒ/ : Vowel [ʏ]	139.20	113.40	1.227	0.2205
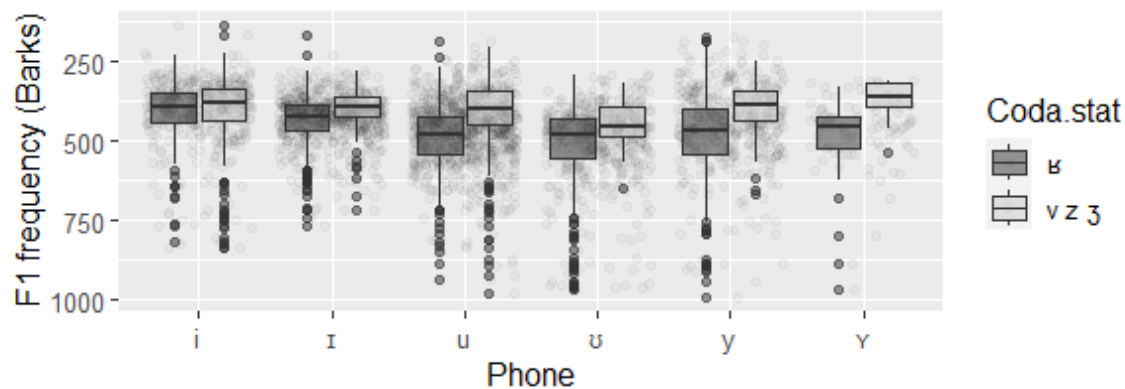
Figure 3. The effects of coda category and vowel allophone on vowel height (F1) in Barks. The y-axis is inverted because higher F1 is associated with lower tongue positions.

Turning to nucleus F2 (Figure 4), the main effects for vowel phonemes confirm that back vowels and rounded vowels exhibit lower F2 than [i], as expected from lower F2 vowels resulting from a more backed tongue position and from lip rounding. Of particular interest for the current study is that [ɪ] also has lower F2 than [i] before /ʁ/ (β=-55.21; p=0.0274), and comparing coefficients reveals that /u/ is similarly more central before /ʁ/ when lax compared to when tense. Before /v z ʒ/, however, [ɪ] is further front than [i] (β=136.3; p=0.0010) and tense [u] also appears to be less peripheral than its lax counterpart, though this should be confirmed in future work with more data. Additionally, vowel duration has an effect on F2 such that vowels with longer durations tend to be more back (i.e., have lower F2) than vowels at shorter durations. These results show that /ʁ/ conditions nucleus position distinctly from the other lengthening consonants; /ʁ/ is associated with more centralisation of lax vowels, but typically more

backing of [u] and [y]. In the following section, we conclude our results by discussing the conditioning of high vowels' degree of diphthongisation.
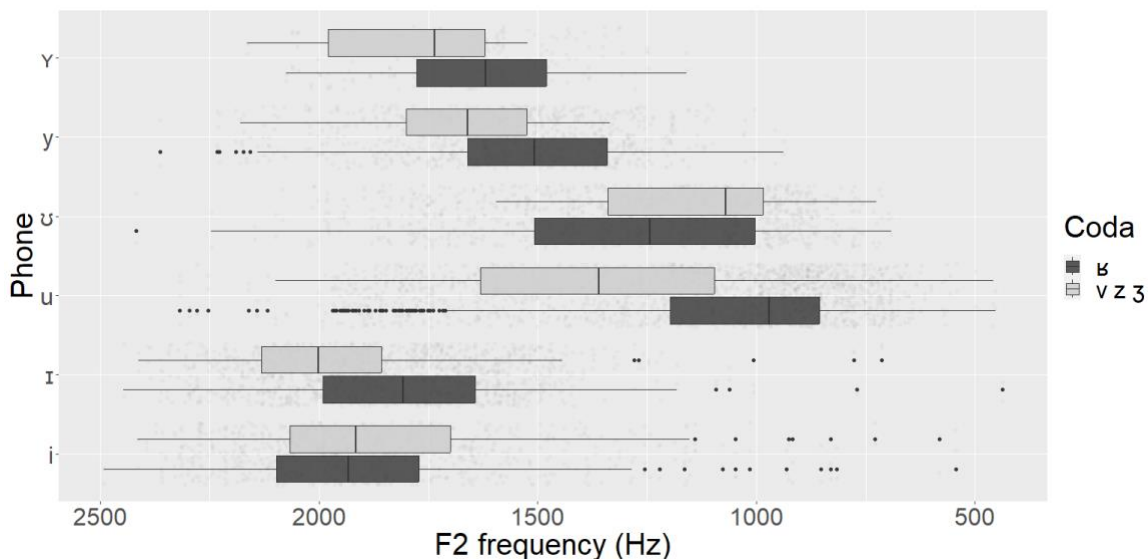
Figure 4. The effects of coda category and vowel allophone on high-vowel backness (F2). The x-axis is inverted, with more front tongue positions (higher F2) being farther left.
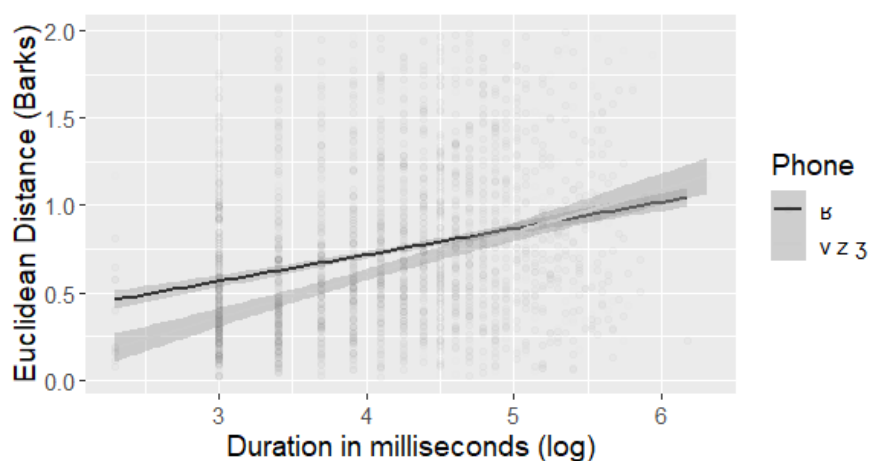
3.3   Degree of diphthongisation

Finally, we ran a mixed-effect linear regression model (Table 4) to predict the degree of diphthongisation (operationalised as the Euclidean distance in F1 and F2 formant space). As illustrated in Figure 5, the degree of diphthongisation of high vowels before lengthening consonants of any type is fairly limited.[6] Abete (2011) reports that vowels are perceived as diphthongal if the Euclidean distance in Barks is greater than 1.8, which is then confirmed for vowels between 160 and 180 ms. in Abete (2018).[7] In this figure, we additionally see that vowels at longer durations are diphthongised to a greater degree than those at shorter durations (β=0.0032; p<0.0001), but we highlight that the degree of diphthongisation is relatively marginal if Abete's perceptual threshold of 1.8 applies to this variety of French (to be confirmed in future work).

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[6] While visual inspection of Figure 5 would suggest that there is an interaction between the coda category and the vowel's duration, Figure 7 will illustrate that this apparent difference is predominantly the consequence of allophones and phonemes differing in vowel duration. The interaction was therefore not included in our statistical model, but preliminary models confirm that the interaction is not significant.

[7] Abete (2018) also reports that the threshold is greater than 1.8 for vowels which are at durations shorter than 160 ms.

Table 4. Mixed-effects linear regression model output predicting the degree of diphthongisation (Euclidean distance).

| Factor	Estimate	Standard error	t-value	p-value
(Intercept)	0.8559	0.1157	7.396	< 0.0001 ***
Vowel duration (log)	0.0032	0.0004	8.874	< 0.0001 ***
Coda /v z ʒ/	-0.1028	0.1379	-0.746	0.4562
Vowel [ɪ]	-0.3141	0.0931	-3.375	0.0007 ***
Vowel [u]	0.4157	0.1468	2.832	0.0049 **
Vowel [ʊ]	0.2591	0.1546	1.676	0.0946 .
Vowel [y]	-0.0597	0.1764	-0.338	0.7352
Vowel [ʏ]	-0.5480	0.1900	-2.884	0.0041 **
Coda /v z ʒ/ : Vowel [ɪ]	-0.0757	0.1155	0.489	0.6246
Coda /v z ʒ/ : Vowel [u]	-0.1201	0.2233	-0.538	0.5913
Coda /v z ʒ/ : Vowel [ʊ]	-0.1448	0.3540	-0.409	0.6827
Coda /v z ʒ/ : Vowel [y]	-0.5192	0.3392	-1.531	0.1269
Coda /v z ʒ/ : Vowel [ʏ]	0.0397	0.4019	0.099	0.9214

Figure 5. The effects of the vowel duration and the coda category on the degree of diphthongisation (Euclidean distance).

Vowels before /ʁ/ are diphthongised to a similar extent as those before other lengthening consonants once the effect of vowel duration is taken into account. Instead, the largest difference in diphthongisation rate is between vowels. As shown in Figure 6, [ɪ] (β=-0.3141; p=0.0007) and [ʏ] (β=-0.5480; p=0.0041) are diphthongised to a lesser degree before /ʁ/ than [i] is, while [u] is diphthongised to a greater degree (β=0.4157; p=0.0049) than [i] is in the same context. Taking into account the far more limited number of tokens of /y/ in the dataset, our results suggest that lax vowels exhibit lesser degrees of diphthongisation on average than their tense counterparts.
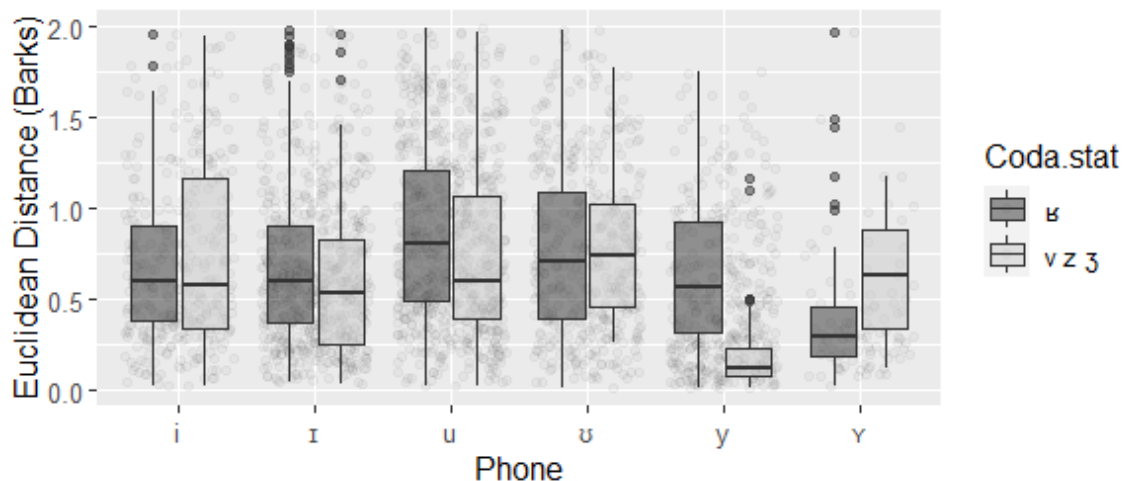
Figure 6. The effect of coda category and vowel allophone on the degree of diphthongisation (Euclidean distance).

Figure 7 visually confirms that duration is the most important factor in conditioning the degree of diphthongisation. For all vowels except [ʏ] (for which there are only 96 tokens), the degree of diphthongisation increases as duration increases and there is generally no clear separation between the distributions (shaded regions) for each coda category for a given vowel allophone. Although these results show that duration is the primary factor which conditions degree of diphthongisation, there are subtle effects found for specific vowels before /ʁ/, particularly for [ɪ], [ʏ], and [u]. In the following section, we discuss how our results for diphthongisation and laxing confirm /ʁ/'s phonological similarity to /v z ʒ/ on one hand, but crucially also exhibits certain distinct phonological patterns.
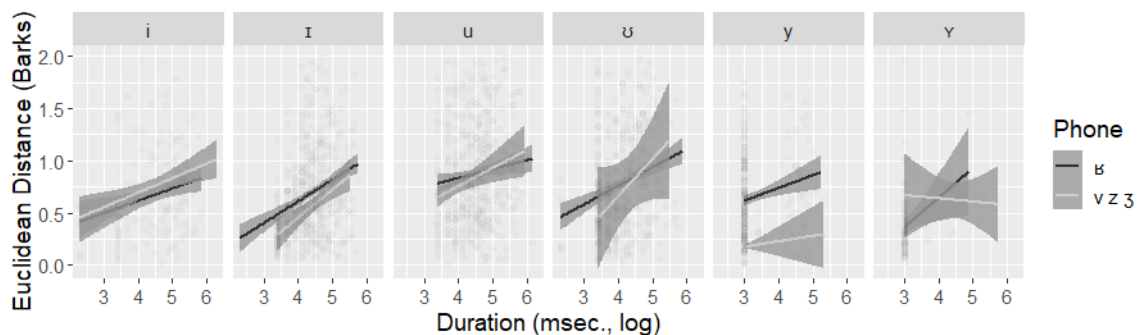
Figure 7. The effects of vowel duration, coda category and vowel allophone on the degree of diphthongisation (Euclidean distance).

4.   Discussion

In this section, we discuss the results of our study investigating the phonological patterns associated with the rhotic compared to other lengthening consonants in Québec French. Section 4.1 unifies our results to discuss the broader phonetic and phonological behaviours associated with the rhotic as compared to other lengthening consonants. Section 4.2 then discusses the phonological implications of these results in treating the rhotic as belonging to a shared natural class with or the same phonologically active class as other lengthening consonants. Section 4.3 concludes with directions for future work and broader contributions of the current paper.

4.1   Phonetic and phonological patterning of /ʁ/

We leveraged three diagnostics from our two test cases (laxing and diphthongisation) to determine the extent to which /ʁ/ conditions the realisation of the high vowels differently than other lengthening consonants (/v z ʒ/): high vowel laxing, nucleus position, and degree of diphthongisation. With respect to laxing, phonological descriptions vary in whether high vowels may surface as lax before any type of lengthening consonant, including the rhotic (see Burness et al. 2022). In our data, approximately 40% of all high vowels were realised as lax before lengthening consonants. Of these lax tokens, however, the vast majority (approximately 85%) occurred before /ʁ/, and /ʁ/ is associated with significantly more high-vowel laxing than the other lengthening consonants. This distinctive behaviour is most prevalent in /i/, where we observe that the laxed counterpart represents the majority variant before /ʁ/. The extreme pattern of /i/ may reflect how, due to its phonetic realisation as both front (higher F2) and unrounded (lower formant values overall), the coarticulatory effects of /ʁ/ are especially likely to be large and perceptible, resulting in separate phonologisation.

Concerning nucleus position, we observe that high vowels before /ʁ/ are typically characterised by higher F1 (generally reflective of lower tongue positions) compared to how they are realised before other lengthening consonants. Furthermore, lax vowels tend to centralise before the rhotic in particular, yielding less extreme F2 values. Put together and coinciding with results for the classification of vowels as tense or lax, these results suggest that the common description of high vowels as being tense before lengthening consonants is generally accurate, but that for speakers in our corpora this generalisation only applies to lengthening consonants other than the rhotic. The results further show evidence for the coarticulatory pressures from the rhotic being distinct, with centralisation and vowel lowering being hallmark effects of the rhotic in particular. Future studies should further probe the time-course of the vowels' articulations to determine whether the phonological and coarticulatory differences show distinct temporal alignments throughout the vowel.

Concerning the degree of diphthongisation, coda category (/ʁ/ or other lengthening consonant) is not the primary determiner of degree of diphthongisation. Rather, duration plays the largest role in that longer vowels undergo greater diphthongisation. A more subtle pattern that emerges from our data is that tense vowels are generally diphthongised

to a greater degree than their lax counterparts, which could partly be an extension of tense vowels' longer durations overall.[8] Given that [ɪ] and [ʊ] are lax and diphthongise to a lesser degree before /ʁ/ while [u] is tense and diphthongises to a greater degree in the same environment, we posit this effect may actually be a result of durational differences between tense and lax vowels.

In short, our results confirm that the rhotic patterns differently from other lengthening consonants, with indications that this difference cannot solely be ascribed to coarticulatory pressures. As such, the following section discusses the phonological implications of our results more broadly with respect to the phonological system in Québec French.

4.2   Phonological implications

Descriptions of /ʁ/ in Québec French (e.g., Walker 1984) have traditionally put it alongside other lengthening consonants with respect to its phonological behaviour, despite its historically distinctive realisations in western varieties of the dialect. With the change in typical rhotic realisation in these varieties including a voiced fricative variant (see section 1), that could then unite it as a clear natural class alongside the other lengthening consonants (all voiced fricatives). However, our results suggest a more nuanced description is required: diphthongisation patterns similarly across all lengthening consonants (including /ʁ/), but laxing appears to treat /ʁ/ quite distinctly in favouring laxing far more frequently than other lengthening consonants. Drawing upon Poliquin's (2006) thesis on high-vowel laxing harmony in Québec French, however, we note that all lengthening consonants are described as being able to trigger high-vowel laxing harmony despite that he describes final-syllable high vowels in lengthening contexts as categorically tense. He therefore proposes a process whereby long high vowels lax (due to syllable shape) and then retense (due to vowel length).

Our results nuance this description in that we find only *variable* (re)tensing of lengthened vowels, with a clear separation in rates between /ʁ/ and the other lengthening consonants. This supports treating those lengthening consonants (/ʁ/ included) as a phonologically active class that could be unified with the change in /ʁ/ realisation due to lengthening and diphthongisation similarity. However, the natural class that most unambiguously patterns alike (clear – as opposed to variable – voiced fricatives, with /ʁ/ excluded) still benefits from being treated as a unit not only for coarticulation, but also for variable rates of retensing application (where /ʁ/ patterns distinctly).

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[8] In addition to this being a pattern for tense-lax pairs in Québec French for intrinsic phonological length (Lamontagne and Goad 2019) and for phonetic duration (Lamontagne 2020), we confirmed that this durational asymmetry was reflected in the phonetic data under analysis.

4.3   Conclusion and future directions

Our results speak to /ʁ/'s membership (or lack thereof) in the group of lengthening consonants in Québec French, which could have shifted as a result of its recent change in realisation. While the current study reveals that /ʁ/ retains properties characteristic of lengthening consonants (it triggers lengthening and diphthongisation), its phonetic and phonological effects (association with tenseness and centralisation) nonetheless justify treating it as distinct. Future work should probe a wider range of social contexts to determine whether the relative formality of the speech under analysis or the sociodemographic profiles of the speakers plays a role in these conclusions.

The examination of social conditioning is particularly appropriate given that diphthongisation can be associated with stigma in other vowels (cf. Côté 2012) and therefore a more casual conversational context and a speaker sample representing a broader range of professional categories could yield different results. Future work should also test vowels of other heights to better understand the role of vowel properties in diphthongisation and nucleus position, as other phonemes would be predicted to show different sensitivity to the centralising effect of /ʁ/. Finally, we hope to have demonstrated the methodological benefits that vowel classification through forced alignment can offer to future crosslinguistic studies of rhotics and to assessments of the phonological status of /ʁ/ in Québec French more specifically.

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