RE-EVALUATING THE ROLE OF DURATION IN LAURENTIAN FRENCH HIGH VOWEL LAXING*

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1. Introduction

Cross-linguistically, lax vowels typically are lower, more central, and have shorter durations than tense vowels (e.g., Adisasmito-Smith 1999), and vowels tend to lax in closed syllables (Féry 2003). One of the most studied phonological processes in French, *loi de position* (e.g., Morin 1986, Lyche 2003, Côté 2008) features mid-vowels which tense in open syllables and lax in closed syllables. Recent work presented in Storme (2017) tests the hypothesis that *loi de position* is a result of vowel reduction induced by vowel shortening, thus resembling duration-based undershoot. In exploring the acoustic properties of *loi de position* on a variety of French spoken in the south of France which strictly follows this process (specifically in Clermont-Ferrand, Auvergne), Storme's results suggest that high vowels show evidence of being affected by a process resembling *loi de position*. Specifically, high vowels show evidence of undershoot in closed syllables and there seems to be an effect of the following consonant. Throughout the paper, Storme expresses intrigue regarding whether non-lengthened high vowel laxing in Laurentian French (e.g., /vit/ [vɪt] *vite* 'fast') might show evidence of resulting from undershoot. As a result of the speculation put forth in Storme (2017), the focus of the present study is to perform three analyses on Laurentian French high vowels in closed final syllables to assess whether laxing may be a result of duration-based undershoot.[1] Our results demonstrate that although undershoot is present, mainly for F2, there is not sufficient evidence to suggest that laxing in Laurentian French is the result of duration-based undershoot.

1.1 Acoustic correlates of lax high vowels in Laurentian French

To probe whether high vowel laxing in Laurentian French may be a result of duration-based undershoot, we must first establish what acoustic correlates distinguish tense vowels from lax vowels in this dialect. Given that Laurentian French high vowel laxing occurs categorically in closed final syllables (e.g., Dumas 1983, Walker 1984, Poliquin 2006, Côté

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[1] Although Storme (2017) compares the effects found for high vowels to *loi de position* in a variety of French that strictly follows the process, we note that *loi de position* is not prevalent in Laurentian French (Côté and Villeneuve 2018) and is therefore not simply an extension of *loi de position* to high vowels.

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2012), we might expect that tense high vowels which occur in open final syllables have longer durations, are higher, and less central than their lax counterparts as is seen typologically for tense versus lax vowels (e.g., Adisasmito-Smith 1999).[2] Some existing work on Laurentian French suggests this is true of duration for high vowels (Martin 2002); other work shows that the opposite is true: (lax) high vowels which are in final closed syllables have longer durations than (tense) high vowels which are in final open syllables (Ouellet et al. 1999, Arnaud et al. 2011). We revisit this issue regarding how tenseness corresponds to duration in this study.

Turning to vowel height and centralisation, we expect to find that lax vowels are lower than tense vowels given that previous research on laxing in Laurentian French generally comes to a consensus that lax vowels are lower than tense vowels (see Burness et al. 2022).[3] The role of centralisation, however, is variable (c.f. Dalton 2011, Arnaud et al. 2011); we hope to clarify what factors may predict centralisation as a part of this study. Given the different vowel positions associated with tense and lax high vowels in Laurentian French, we anticipate that tense and lax vowels have two separate acoustic targets which will be most distinct at longer vowel durations.

1.2 Current study

We will test our primary research question regarding whether Laurentian French high vowel laxing results from duration-based undershoot by using three separate analyses: (1) whether tenseness is a correlate for duration and corresponds to expected acoustic outputs for Laurentian French high vowels, (2) whether lax vowels are both lower and more central at shorter durations than tense vowels, and (3) whether the following consonant serves as a predictor of undershoot in lax tokens. For high vowel laxing to show evidence of duration-based undershoot (based on the model proposed in Lindblom 1963), we would expect to find evidence that the lax vowels are not fully reaching the acoustic targets that are reached by tense vowels, particularly at shorter durations.

Given the acoustic correlates of Laurentian French high vowels, we have predictions for each of our three analyses that we would expect if lax vowels were to show evidence of duration-based undershoot. For our first analysis regarding whether the results predicting duration according to tenseness are symmetrical with vowel height and centralisation, we would expect that lax vowels would be shorter, lower, and more central than their tense counterparts; in other words, shorter vowels would not seem to be reaching their acoustic targets. Turning to our second analysis, we test whether lax vowels show evidence of undershoot at shorter durations in comparison to tense vowels. We would expect that lax vowels at shorter durations would be lower and more central than their tense

[2] The status of laxing before lengthening consonants /v z ʒ ʁ vʁ/ is variable (see Sigouin and Arnaud 2015, Burness et al. 2022, Lamontagne et al. 2023b). Although we include instances of high vowels before lengthening consonants in this study, we categorise them separately from tense vowels in open syllables and lax vowels in closed syllables.

[3] Here, we use the term centralisation to refer to the lax front vowels being more back than the tense ones and the lax back vowels being more front than the tense back ones.

counterparts if they were to show evidence of undershoot.[4] Finally, we address our third analysis which probes whether different consonants reveal evidence of undershoot for lax vowels. We would expect, if laxing were to be a direct result of undershoot, that evidence of this phenomena is present before all codas which induce laxing.

1.3 Summary

In this study, we test whether high vowel laxing in Laurentian French could be the result of duration based undershoot. In section 2, we describe the corpora from which the data were extracted along with the coding and statistical analyses which were applied to the data. Then, the results are presented in section 3 according to our three analyses: tenseness as a predictor of duration and vowel position (section 3.1), duration and tenseness as a predictor of vowel position (section 3.2), and duration and coda as a predictor of vowel position (section 3.3). Finally, in section 4 we unify our results based on formant to assess whether patterns of undershoot are present before summarising our findings and providing directions for future work.

2. Methodology

In this section, we describe the methodology that we employed to test our primary question regarding whether Laurentian French high vowel laxing is a process resulting from duration-based undershoot. We detail the two corpora of formal Laurentian French from which we extract our data (section 2.1). Then, we describe the preparation of our data along with how variables were coded (section 2.2). We conclude this section by describing the mixed-effects linear regressions that we use to analyse the data (section 2.3).

2.1 Corpus

Our study uses data from 26 speakers that were extracted from two corpora of televised interviews with Québécois elites and celebrities (Villeneuve 2017): *On prend toujours un train pour la vie* (henceforth *Un Train*) and *Téléjournal Le Point* (henceforth *Le Point*). Although the two corpora were created with the intent to be able to compare two types of formal Québec French speech, our analyses here do not consider sociolinguistic variables. Stylistic differences between *Un Train* and *Le Point* have been found for morphosyntactic variables (e.g., Villeneuve et al. 2021) as well as for high vowels before lengthening consonants (Lamontagne et al. 2023b). We first conducted separate analyses comparing the corpora. We found that combining the two corpora do not obscure the general patterns and the subsequent findings of the work presented here.

[4] Other research on vowel undershoot in French shows that shorter vowels are more central, but not necessarily lower (Gendrot and Adda-Decker 2015). We revisit this finding when presenting out results.

2.2 Data extraction and coding

The data used in this study were first force aligned using the *Montreal Forced Aligner* (McAuliffe et al. 2017); then, F1 and F2 were measured at the vowel midpoint and vowel duration was also measured. These data were originally prepared and extracted as part of a collaborative project (see Lamontagne et al. 2023a). After data extraction, all tokens of /i/ in final syllables were identified. We selected /i/ rather than the other high vowels for this study given that /i/ occurs before all possible codas in the lexicon whereas /y/ and /u/ do not; therefore, only analysing /i/ allows us to best observe possible coarticulatory effects. Additionally, Burness et al. (2022) find that lax /i/ is consistently lower and more central than tense /i/, whereas it is not as clear how lax /y/ and /u/ are consistently distinguishable from tense /y/ and /u/. To this end, /i/ gives us a baseline for expected differences between lax /i/ and tense /i/ that the other high vowels do not.

Duration was first measured and then was log transformed prior to statistical analysis. Further, tokens at durations above 150 milliseconds were excluded from our analysis as those values constituted outliers in our dataset. We additionally excluded tokens which had an F1 higher than 650 Hz and 1200 Hz as these constituted outliers in our data set and eliminated values which are unlikely to fall into the expected range for /i/. Tokens before complex codas were also excluded to avoid any effects of the additional consonant(s).

Tenseness was coded as a three-level factor (lax, tense, or variable) according to syllable environment given that high vowels lax in syllables not closed by lengthening consonants (e.g., Walker 1984), where the status of laxing is unclear (see Burness et al. 2022). Tokens in open syllables were marked as tense, those in syllables closed by a lengthening consonant (i.e., /v z ʒ ʁ/) as variable, and those which preceded all other consonants as lax. Additionally, tokens that were marked as lax were coded as a six-level factor (voiceless stop, voiced stop, voiceless fricative, nasal, /l/, and /j/) according to the manner and voicing of the coda.[5] We include these factors to probe the role of coarticulation on duration-based undershoot.

2.3 Statistical analysis

We analyse the data extracted from *Le Point* and *Un Train* according to each of our research questions by running mixed-effects linear regressions using the *lme4* package (Bates et al. 2015) in *R* (R Core Team 2022). For each of our analyses, we include both speaker and lexical item as random intercepts. In our first analysis looking at whether lax vowels reach their expected acoustic targets and correspond to decreased duration, we ran three models to predict the relevant factors based on tenseness: (1) duration, (2) F1 frequency, and (3) F2 frequency. To conduct our second analysis regarding whether lax vowels show evidence of undershoot at shorter durations, we ran one model which predicts F1 frequency and a second which predicts F2 frequency. In both models, we include duration, tenseness, and the interaction between these two variables as factors. Finally, we ran two models

[5] We additionally ran a separate analysis according to place of articulation rather than manner. However, this model did not yield any statistically significant findings.

(predicting F1 and F2 frequency respectively) to conduct our third analysis to determine whether evidence for undershoot is present regardless of coda. We include duration, coda, and the interaction of these two variables as factors in each model. In the following section, we present the results of these statistical models along with the accompanying figures.

3. Results

In this section, we present the figures and tables of results for the 5,587 tokens extracted from the corpora *Un Train* and *Le Point* (Villeneuve 2017) which are used to assess our primary question regarding whether lax vowels show evidence of undershoot. We begin by presenting the results of our first analysis regarding whether lax /i/ is the lowest, the furthest back, and the lowest in comparison to other tokens (section 3.1). We then continue the section with our results which analyse how duration effects tokens of /i/ for all degrees of tenseness (section 3.2). Finally, we conclude in section 3.3 by presenting the results from our analysis targeting the coda's role in conditioning undershoot for tokens of lax /i/.

3.1 Duration versus vowel position

As illustrated in Figure 1 and confirmed by our regression model (see Table 1), tokens of /i/ in variable contexts (i.e., before lengthening consonants) have longer durations than before lax /i/ (β=0.2339; p=0.0002), and tense /i/ is shorter than lax /i/ (β=-0.1752; p<0.0001). This finding is consistent with trends for French whereby lax vowels in closed final syllables are longer than tense vowels in open final syllables (Ouellet et al. 1999). However, this is not consistent with the typological tendency for lax vowels to be shorter (e.g., Adisasmito-Smith 1999). We also see that /i/ before lengthening consonants generally are longer than those before lax /i/, demonstrating that phonological length corresponds to phonetic length for tokens which precede these consonants.

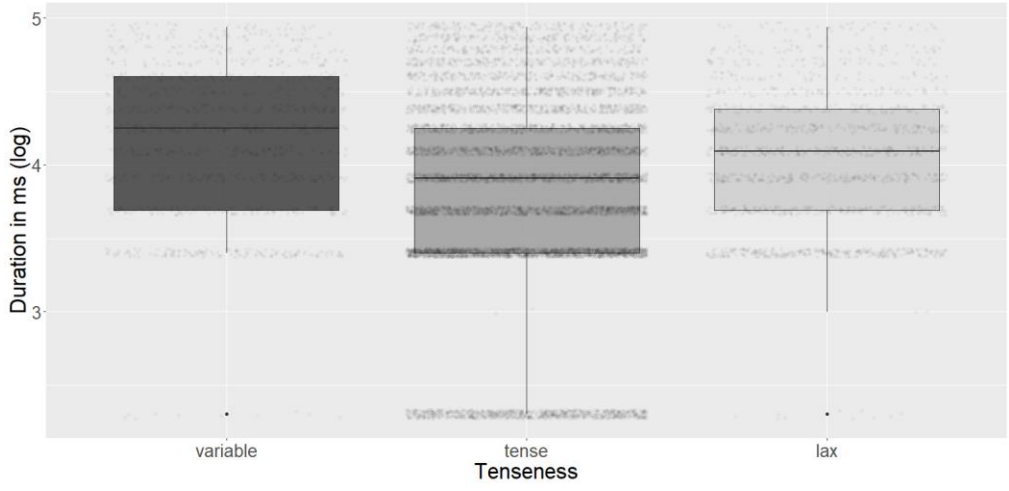

Figure 1. Duration of /i/ by tenseness.

Table 1. Mixed-effects linear regression model output predicting duration of /i/ by tenseness.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	3.9779	0.04298	308.0547	92.544	< 0.0001	***
Variable	0.2339	0.06204	773.1603	3.770	0.0002	***
Tense	-0.1752	0.04341	1187.2632	-4.037	< 0.0001	***

Turning to our analyses regarding vowel height and frontness, Figure 2 depicts vowel height (F1) and frontness (F2) by tenseness. In terms of vowel height, we see that tense /i/ is higher (lower F1) than lax /i/. Additionally, /i/ in the variable context is higher (lower F1) than lax /i/ but lower (higher F1) than tense /i/. Our model output (see Table 2) confirms that /i/ in variable contexts is higher (lower F1) than lax /i/ (β=-28.341; $p<0.0001$), and /i/ is even higher (lower F1) than lax /i/ (β=-40.906; $p<0.0001$). Our results here are consistent with the existing literature on high vowel laxing in Laurentian French which find that lax high vowels are often lower than tense ones (see Burness et al. 2022).

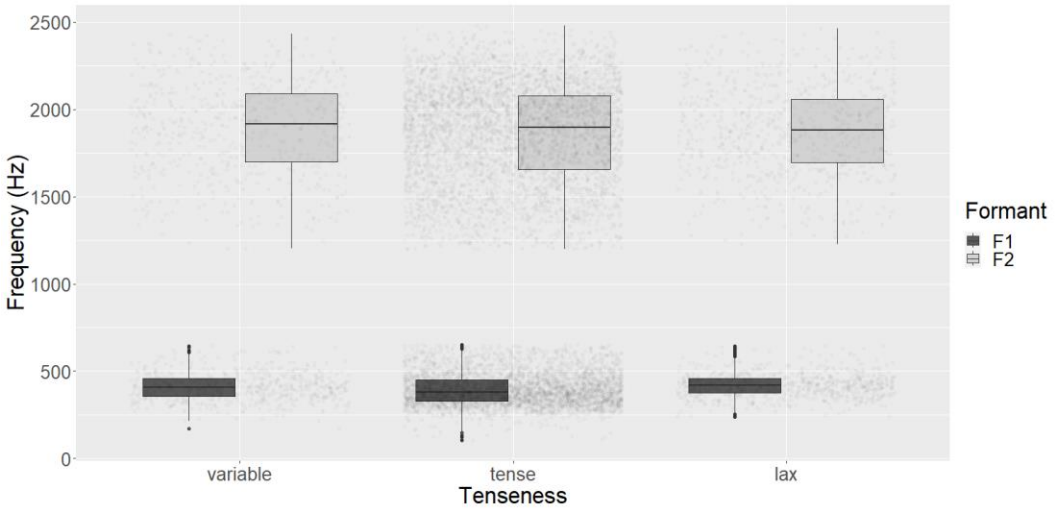

Figure 2. F1 and F2 frequency of /i/ by tenseness.

Table 2. Mixed-effects linear regression model output predicting F1 frequency of /i/ by tenseness.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	431.044	7.840	42.762	54.980	< 0.0001	***
Variable	-28.341	6.358	478.734	-4.457	< 0.0001	***
Tense	-40.906	4.755	600.809	-8.603	< 0.0001	***

In evaluating vowel frontness (F2), we see, in Figure 2, that both tense /i/ and /i/ in variable contexts are more front (higher F2) than lax /i/, although tense /i/ is marginally so. The statistical model confirms what we see in Figure 2 only for /i/ in variable contexts in that tokens in this context are more front than lax /i/ (β=59.20; p=0.0081). Our results additionally demonstrate that F2 does not play a significant role in distinguishing tense /i/ from lax /i/ (c.f. Burness et al. 2022), while it does further distinguish /i/ in variable contexts from lax /i/. We posit this may reflect the variable role of F2 in classifying lax high vowels in Laurentian French but leave further exploration of centralisation of lax vowels to future work.

Table 3. Mixed-effects linear regression model output predicting F2 frequency of /i/ by tenseness.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	1884.04	21.44	64.26	87.890	< 0.0001	***
Variable	59.20	22.24	368.56	2.662	0.0081	**
Tense	-11.00	16.51	446.03	-0.666	0.5058	

Based on the results presented in this section, there is not yet evidence of undershoot for lax high vowels in Laurentian French. If there were to be evidence in this first analysis, we would minimally expect that lax /i/ is lower than tense /i/ *and* that lax /i/ is shorter than tense /i/. Instead, our results show that although lax /i/ is lower than tense /i/, it is *longer* than tense /i/. In the next section, we analyse whether there is evidence of undershoot when using duration as a predictor.

3.2 Vowels at shorter durations

As shown in Figure 3, we see that tense /i/ has a higher F1 value at shorter durations than lax /i/, and /i/ in variable contexts has a lower F1 than lax /i/. At longer durations, however, tense /i/ has a much lower F1 than lax /i/ while /i/ in variable contexts has an F1 only slightly lower than that of lax /i/. The results of our mixed-effects linear regression model (see Table 4) confirm that tense /i/ is lower (higher F1) at shorter durations (β=75.3325; p=0.0050) and higher (lower F1) at longer durations (β=-29.1854; p<0.0001) than lax /i/. Our statistical model cannot confirm that /i/ in variable contexts is lower or higher than lax /i/, indicating that the two have approximately the same acoustic target in terms of height. Based on these results, we do not see evidence of undershoot for lax /i/ because it remains at relatively the same height regardless of vowel duration. Rather, tense /i/ shows evidence of undershoot because it is lower at shorter durations than longer durations. This may indicate that tokens of tense /i/ at shorter durations have decreasing articulatory energy, such as that of high vowel devoicing in final open syllables (see Fagyal and Moisset 1999). We leave exploration of word-final vowel devoicing in these corpora to future work.

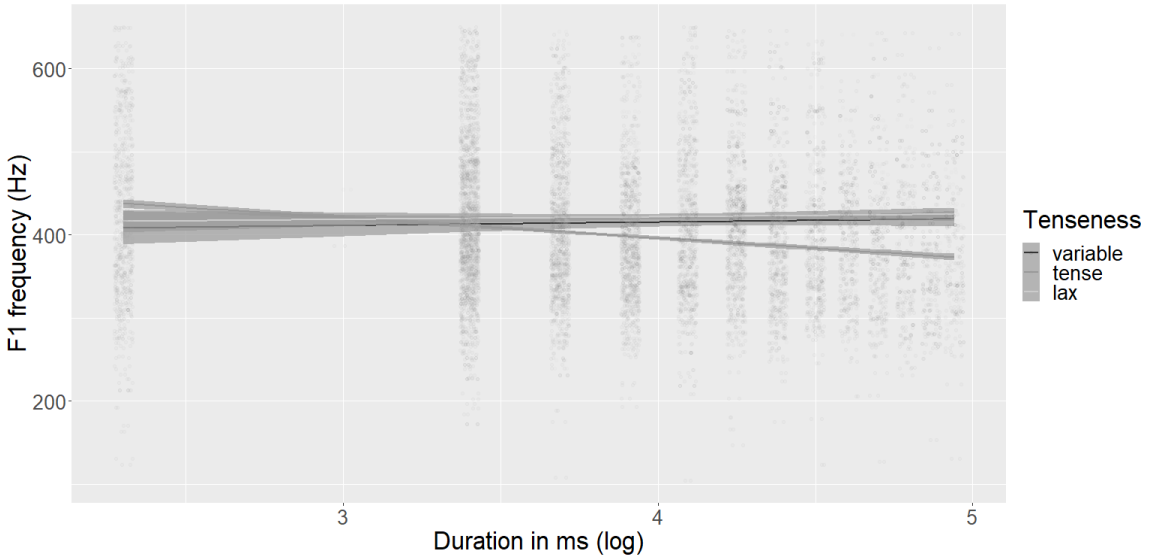

Figure 3. F1 frequency of /i/ by duration and tenseness.

Table 4. Mixed-effects linear regression model output predicting F1 frequency according to duration and tenseness.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	408.3112	26.5432	2417.5813	15.383	< 0.0001	***
Duration (log)	5.7249	6.2998	4405.9802	0.909	0.3635	
Variable	-26.8690	40.3540	4340.0665	-0.666	0.5056	
Tense	75.3325	26.8478	4243.4336	2.806	0.0050	**
Duration (log) : Variable	0.9513	9.7191	4319.9064	0.098	0.9220	
Duration (log) : Tense	-29.1854	6.6187	4410.7735	-4.410	< 0.0001	***

Turning now to our analysis of F2, we see in Figure 4 that /i/ in variable contexts is more front at shorter durations than lax /i/, while tense /i/ is more front at shorter durations than lax /i/. Further, all three variants appear to converge to roughly the same fronted acoustic target as duration increases. Indeed, our mixed-effects model (see Table 5) confirms that as duration increases, so does the degree of frontness regardless of tenseness (β=109.56; $p<0.0001$). We do see a marginal effect, however, for /i/ in variable contexts in that it is slightly more front than lax /i/ (β=56.74; $p=0.0758$).

In terms of frontness, our results demonstrate that all three variants show evidence of undershoot at shorter durations. This result is consistent with previous work on French in that shorter vowels are more central without necessarily being lower (Gendrot and Adda-Decker 2015). We hypothesise this may be because shorter vowels are more prone to coarticulation (Lindblom 1963), however we leave the testing of this hypothesis on the present data to future work. We conclude our results in the following section which probes the role of coda classification on patterns of undershoot in tokens of lax /i/.

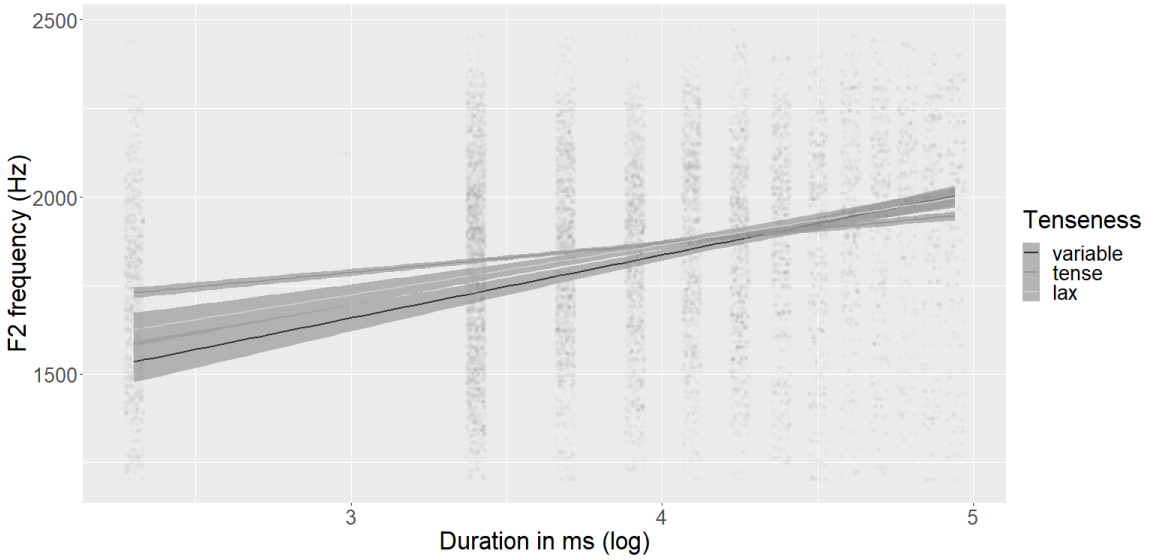

Figure 4. F2 frequency of /i/ by duration and tenseness.

Table 5. Mixed-effects linear regression model output predicting F2 frequency according to duration and tenseness.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	1440.77	86.13	3952.97	16.728	< 0.0001	***
Duration (log)	109.56	20.98	4519.41	5.223	< 0.0001	***
Variable	-195.92	131.71	4380.72	-1.488	0.1369	
Tense	115.37	88.89	4274.95	1.298	0.1944	
Duration (log) : Variable	56.74	31.95	4339.31	1.776	0.0758	.
Duration (log) : Tense	-25.71	21.98	4521.55	-1.170	0.2421	

3.3 Effects of the following consonant

To conclude our series of analyses testing whether lax high vowels in Laurentian French could be the results of duration based undershoot, we probe the role of the following consonant in tokens of lax /i/. In Figure 5, we see that generally vowels are lower (higher F1) as duration increases. For tokens of /i/ before /l/ and nasals, however, we see that the vowel is higher (lower F1) as duration increases. We additionally see that tokens before /l/ tend to be lower (higher F1) than those before voiceless plosives at shorter durations, while at longer durations tokens before /l/ tend to be higher (lower F1) at longer durations.

Our statistical model (see Table 6) confirms that vowels generally lower (higher F1) as duration increases (β=26.344; p=0.0046) than tokens before voiceless stops. However, /i/ before both /l/ (β=-33.346; p=0.0050) and nasals (β=-44.030; p=0.0247) are higher (lower F1) as duration increases and are lower (higher F1) at shorter durations (β=113.249; p=0.0171 and β=194.779; p=0.0137 respectively) than /i/ before voiceless stops. We

additionally see a marginal effect for /i/ before /j/ in that the vowel is higher (lower F1) as duration increases (β=-32.574; p=0.0708) in comparison to voiceless stops. To this end, we see evidence of undershoot for tokens of /i/ before /l/ and nasals in that their acoustic targets are not met at shorter durations. With the addition of the marginal effect for /i/ before /j/, we hypothesise that sonorants and obstruents may result in two separate F1 acoustic targets for lax vowels. We leave testing of this hypothesis to future work.

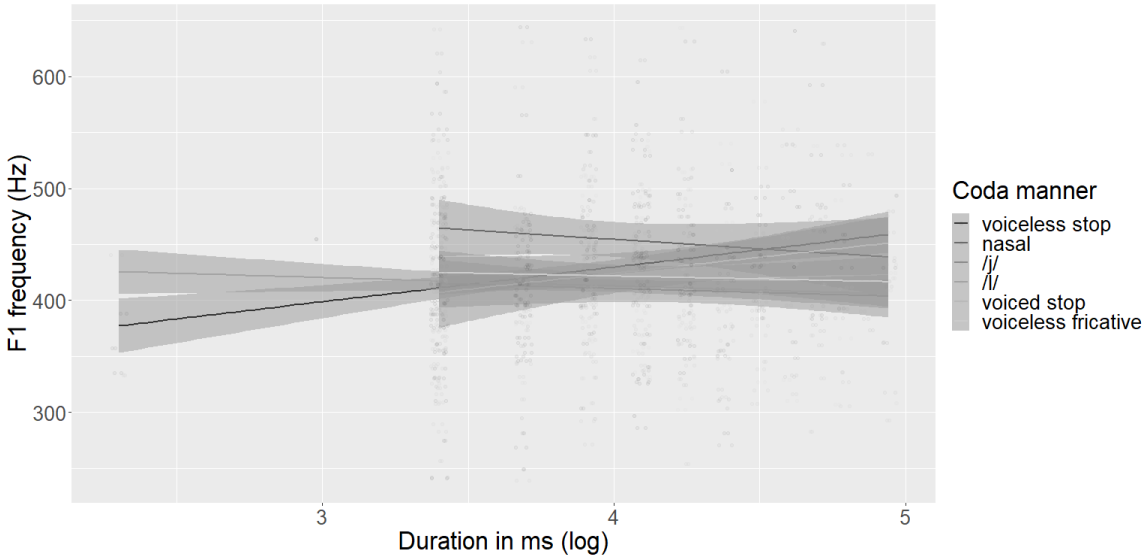

Figure 5. F1 frequency of lax /i/ by duration and manner of the following consonant.

Table 6. Mixed-effects linear regression model output predicting F1 frequency according to duration and coda for tokens of lax /i/.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	326.989	37.616	700.926	8.693	< 0.0001	***
Duration (log)	26.344	9.273	694.734	2.841	0.0046	**
Nasal	194.779	78.820	660.245	2.471	0.0137	*
/j/	109.485	77.171	667.130	1.419	0.1564	
/l/	113.249	47.382	690.556	2.390	0.0171	*
Voiced stop	-34.103	116.786	639.104	-0.292	0.7704	
Voiceless fricative	55.445	74.342	693.600	0.746	0.4560	
Duration (log) : nasal	-44.030	19.554	669.619	-2.252	0.0247	*
Duration (log) : /j/	-32.574	18.001	681.813	-1.810	0.0708	.
Duration (log) : /l/	-33.346	11.839	689.686	-2.817	0.0050	**
Duration (log) : voiced stop	5.065	27.700	627.692	0.183	0.8550	
Duration (log) : voiceless fricative	-15.846	18.173	690.486	-0.872	0.3836	

Regarding our results predicting frontness (F2), Figure 6 illustrates that, regardless of coda, F2 converges to approximately the same target at longer durations. At shorter durations, /i/ tends to be more back (lower F2), while at longer durations it tends to be more front (higher F2). This result is confirmed by our statistical model (see Table 7) in that tokens of /i/ are more front (higher F2) as duration increases (β=104.863; p=0.0013).

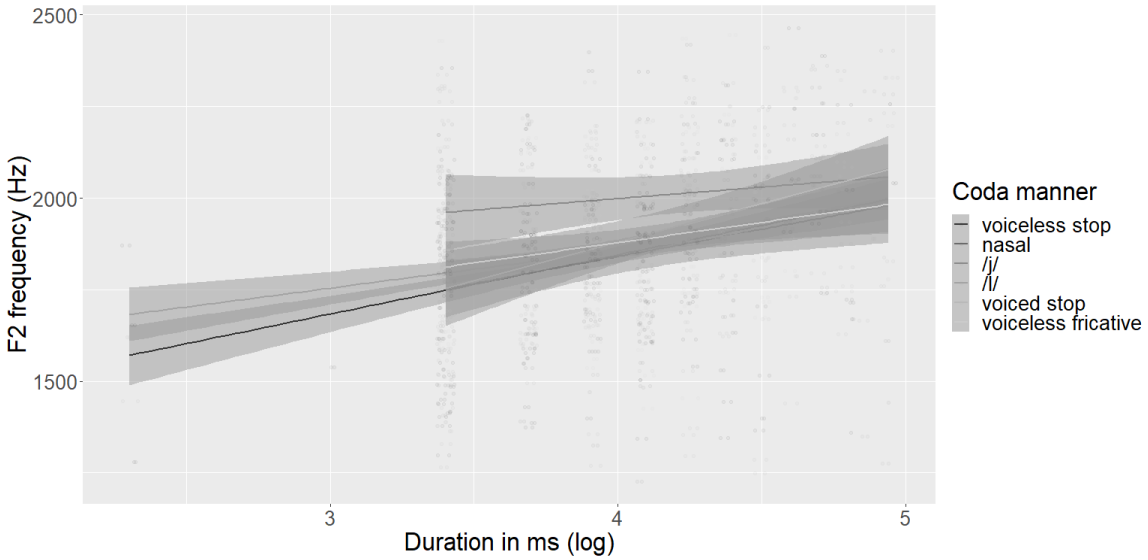

Figure 6. F2 frequency of lax /i/ by duration and manner of the following consonant.

Table 7. Mixed-effects linear regression model output predicting F2 frequency according to duration and coda for tokens of lax /i/.

Factor	Estimate	Standard Error	df	t value	p value	
(Intercept)	1455.321	131.889	686.576	11.034	< 0.0001	***
Duration (log)	104.863	32.494	649.994	3.227	0.0013	**
Nasal	-6.852	292.595	597.725	-0.023	0.9813	
/j/	67.072	290.079	662.991	0.231	0.8172	
/l/	46.354	169.781	675.602	0.273	0.7849	
Voiced stop	-7.972	428.454	658.183	-0.019	0.9852	
Voiceless fricative	87.847	266.121	671.609	0.330	0.7414	
Duration (log) : nasal	-1.023	71.883	621.159	-0.014	0.9887	
Duration (log) : /j/	-9.753	65.230	633.117	-0.150	0.8812	
Duration (log) : /l/	-8.554	41.800	639.842	-0.205	0.8379	
Duration (log) : voiced stop	15.442	102.012	654.429	0.151	0.8797	
Duration (log) : voiceless fricative	-23.716	64.907	652.084	-0.365	0.7150	

From the results presented here, we see that there is evidence of undershoot for F2 given that the frequency is lower at shorter durations than at longer durations. Coda is not a significant predictor of vowel frontness as shown by our model; this pattern of F2 undershoot effects lax /i/ regardless of following consonant. This is, like our results in section 3.2, consistent with previous work on French which shows that vowels at shorter durations are more central without necessarily being lower (Gendrot and Adda-Decker 2015). In the following section, we discuss how lax /i/ does not generally show undershoot patterns along F1, as well as the general pattern of F2 undershoot.

4. Discussion and conclusion

In this section, we discuss the results of our study investigating whether lax high vowels in Laurentian French show evidence of undershoot. We combine the results of our study to discuss whether laxing could be interpreted more broadly as resulting from F1 undershoot section 4.1) as well as F2 undershoot (section 4.2). We conclude in section 4.3 by highlighting directions for future work and the contributions of the present study.

4.1 F1 undershoot: Effect of the following consonant

In this study we undertook three analyses to probe for evidence that laxing results from duration-based undershoot. Specifically focusing on our results regarding vowel height (F1), we see from our results in section 3.1 which predicted duration and vowel position, tokens of tense /i/ and tokens of /i/ before lengthening consonants are both shorter than tokens of lax /i/. If laxing were to be a result of duration-based undershoot, we would expect the reverse: tense /i/ and tokens before lengthening consonants would both be longer than lax /i/. Our first analysis therefore does not reveal evidence of undershoot along F1.

Turning now to our results predicting vowel height by duration and tenseness which were presented in section 3.2, we find that tense /i/ is lower than lax /i/ at shorter durations but higher than lax /i/ at longer durations. Like the results of our first analysis, if laxing were to be a result of duration based undershoot we would expect that lax /i/ would be lower at both shorter and longer durations than tense /i/. We would additionally expect duration to be a predictor of undershoot in that tokens of lax /i/ at shorter durations would be lower than those at longer durations. However, this does not appear to be the case; we do not see evidence of duration-based undershoot along F1 according to the results of our second analysis.

To conclude this section, we discuss the impact of the following consonant for tokens of lax /i/. Generally, we find that tokens of this type tend to be lower at longer durations than they are at shorter durations. Were laxing to be a result of duration-based undershoot, we would expect tokens of lax /i/ to be lower at shorter durations than they are at longer durations. Given that we find the opposite effect, laxing does not appear to be the result of F1 undershoot. However, we do see patterns of undershoot before specific codas: significant effects before /l/ and nasals as well as a marginal effect before /j/. We posit this effect may be an indication of word final sonorant lengthening which is attested for French (O'Shaughnessy 1981) in that the consonant may be causing greater coarticulatory effects

on the vowel at shorter durations than at longer durations. Overall, our three analyses demonstrate that there is not sufficient evidence that laxing of /i/ in Laurentian French is a result of F1 undershoot. In the following section we continue the discussion of our results by synthesising the evidence of F2 undershoot found in our data.

4.2 F2 undershoot: An overarching effect

As discussed in the previous section, high vowel laxing in Laurentian French does not appear to be a result of undershoot along F1. Turning now to the role of F2, the results for our first analysis comparing vowel position to duration demonstrate that tense /i/ and lax /i/ are not significantly different along F2. If this analysis were to reveal evidence of undershoot, we would anticipate that tense /i/ would be more front than lax /i/ as well as longer than lax /i/. Because this result is not found, our first analysis does not yield any evidence of F2 undershoot.

Regarding now our second and third analyses which tested whether F2 showed undershoot at shorter durations according to tenseness and coda respectively, our results demonstrate that duration is the sole significant predictor of frontness: vowels at shorter durations are not as front as vowels at longer durations. In this regard, lax /i/ does show evidence of F2 undershoot, although this effect is not exclusive to these tokens because both tense /i/ and /i/ in variable contexts are also subject to undershoot effects as shown in by our results. If laxing were to be the result of undershoot, we would expect that lax /i/ is subject to undershoot while tense /i/ is not, or that lax /i/ is undershot to a greater extent than tense /i/. However, our results demonstrate that both tense /i/ and lax /i/ are undershot to a similar extent; these second and third analyses do not reveal evidence which implies laxing is a result of duration-based undershoot. Rather, this result is consistent with previous work which shows centralisation occurs in shorter vowels (Gendrot and Adda-Decker 2015). As a result of the three analyses for F2, we see there is not sufficient evidence that laxing of /i/ is a result of F2 undershoot.

4.3 Summary and implications

Our results suggest that high vowel laxing in Laurentian French is plausibly not a result of duration-based undershoot given that neither F1 nor F2 seem to be significantly affected by such patterns. Additionally, we find that vowel duration has a significant impact on high vowel's realization in that F2 appears to be influenced by duration to a greater degree. While the present study probed for the presence of F1 and F2 undershoot, future work should seek to elucidate the role of the first two formants in laxing. A weakness of this study is that only /i/ was tested to best be able to explore coarticulatory effects; to better asses whether laxing is a result of undershoot, /y/ and /u/ should additionally be analysed given that /y/ and /u/ do not always have the same acoustic cues as /i/ when lax (Burness et al. 2022). Further, we may additionally examine word-medial high vowels that would be subject to laxing harmony (Poliquin 2006), such as Storme (2017) explored for *loi de position*. Additionally, cases of laxing harmony may allow us to observe effects of coarticulation from the following vowel, which was tested as a predictor for harmony in

Lamontagne 2020, and to examine effects of the following consonant on both tense and lax vowels, rather than just lax vowels. Overall, the results of this paper provide a better understanding regarding how duration influences the acoustic cues that we have come to associate with tenseness that we can use to better inform our understanding of Laurentian French high vowel laxing.

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