PROSODIC EFFECTS ON L2 FRENCH VOWELS: A CORPUS-BASED INVESTIGATION

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ABSTRACT

We examine the effects of prosodic strengthening on the acoustic realization of L2 French oral vowels. We analyse 12,283 vowels produced by 20 learners of French (L1 Spanish and English) and 10 native speakers according to different prosodic positions: (i) IP-final (ii) AP-final (obligatory accent) or AP-initial (initial non-obligatory accent) and (iii) word-internal unaccented. We computed the convex hull area of F1/F2 and F2/F3 spaces, Euclidean distances and vowel durations. Results show that the L2 vowel space is expanded in strong prosodic positions. Differently from what we observe for native French speakers, vowel expansion does not consistently reflect the prosodic hierarchy for the two groups of learners. We discuss these results in the light of L2 acquisition phonology.

Keywords: prosodic strengthening, L2 French vowels, vowel space

1. INTRODUCTION

It has been shown that both consonants and vowels in strong prosodic positions are produced with increased articulatory effort and expand farther apart within the vowel space. Such phenomenon, called *prosodic strengthening*, has been thoroughly investigated in English [6], French [11, 12], and Korean [8]. According to [12, 13], the prosodic strengthening of French vowels contributes to the enhancement of some phonological features and to the maximisation of phonetic cues. Segments are more *canonical* due to the reinforcement of certain phonological features when they are produced in prosodically strengthened positions (i.e., prominent or accented syllables), in words under contrastive focus and/or segments near the edge of prosodic domains such as the Accentual Phrases (AP) or Intonational Phrases (IP). [4, 12, 13] claim that prosodic strengthening can also be seen as a reinforcement of vowel sonority (sonority expansion) due to the increased aperture motivated by the presence of prosodic prominence.

[14] show that prosodic strengthening reflects the prosodic hierarchy in French: the higher the prosodic domain (syllable < AP < IP), the higher the acoustic expansion and the hyper-articulation of vowels. Similarly, in English, vowels produced at IP-initial position are more dispersed within the vowel space than those in accented positions [6]. Yet, it is unclear whether prosodic strengthening occurs similarly in other languages. For instance, according to [19, 20] the presence of pitch accents and/or lexical stress is not a good predictor of the acoustic expansion of Spanish vowels.

Studies investigating the effects of prosodic strengthening in L2 speech are still scant. [9] report that effects of the L1 prosodic hierarchy can be observed in the production of L2 English consonants /b, p/ produced by Korean speakers: VOT values change as a function of the prosodic hierarchy of Korean, i.e. the prosodic strengthening of the L1 (Korean) is mapped to L2 English. As for the acoustic properties of L2 vowels as a function of their prosodic position, our knowledge is still limited. [1] claim that the acoustic patterns of L2 French vowels produced by four English speakers are not affected by the presence/absence of pitch accents.

In this investigation, we try to replicate these studies in L2 French by examining vowel quality as produced by learners of different L1s (Spanish and British). We examine (a) whether the acoustic expansion of L2 French vowels is affected by their prosodic position and, if so, (b) to what extent vowel expansion reflects the prosodic hierarchy of the target language. Finally, we discuss whether prosodic strengthening is conditioned by the L1: if so, we would expect an L1 positive transfer for English learners, and an L1 negative transfer (i.e. no strengthening) for Spanish learners.

2. CORPORA AND METHODS

2.1. Participants and materials

We analyse the speech of 30 speakers from two corpora: (i) the COREIL corpus [22] and (ii) the Aix-Ox corpus [14] (gender balanced groups). This includes 10 Spanish learners of L2 French (L2FR-SP), 10 British learners of L2 French (L2FR-EN), 10 French native control speakers (L1FR). Speakers

read nine quasi-identical short passages in French describing every-day events (approx. 1 min each), for a total of ~15k vowels. At the time of recording, learners were attending L2 French courses at the National University of Mexico (L2FR-SP) and at the University of Oxford (L2FR-SP) at B1 or B2 levels. Participants' profiles are reported in Table 1.

Table 1: Description of participants' profile. SD in brackets.

Group	N. of part.	Avrg. age	Level
L1FR	10	35 (14)	Natives
L2FR-SP	10	25 (6)	B1/B2
L2FR-EN	10	22 (2)	B1/B2

2.2. Linguistic annotations

The two corpora were transcribed with similar orthographic conventions and are aligned at the following levels: inter-pausal units, words, syllables and phones. We performed an enriched orthographic transcription for mispronunciations, repairs, errors and hesitations that were not originally annotated in the corpora, and carried out a careful manual correction of phone boundaries. Phone labels accounted for canonical pronunciations in the case of L2 French.

Three following prosodic positions were retained for this study [10, 15]:

- IP-final
- AP-edge, including AP-final (obligatory accent) and AP-initial (non-obligatory accent on the first syllable of the first content word)
- WD (word-internal) non-accented

We followed a syntax-to-prosody mapping approach following [22] for robust cross-comparisons between native and non-native speech. This was carried out in two steps: (i) prediction of different prosodic positions according to the syntactic structure, (ii) verification of the predictions on the signal.

In the first step, IP-final position was associated to right edges of coordinated clauses, root clauses and extra-sentential elements. Vowels produced in IP-initial positions were excluded from the analysis since the frequency of certain segments was unbalanced, representing a problem for the statistical analysis and for the calculation of the Polygon area (see section 2.3). AP-edge position was associated to (a) the last vowel of any AP (defined as any lexical word and their related grammatical words on the left side), and (b) the first vowel of the first content word of APs. WD position was associated to the remaining vowels.

In the second step, we carried out a semi-automatic analysis with *Prosogram* [18]. We inspected the f0 contour stylisation. Vowels produced with any melodic movement (falling, rising or dynamic) spanning more than 2 semitones with a glissando threshold of $0.32/T^2$ were manually labelled as IP-final or AP-final according to afore-mentioned syntax-to-prosody mapping rules.

2.3. Vowels and acoustic metrics

The following set of French oral vowels were considered in the analysis: /i, e, ɛ, a, o, ɔ, u, y, ø, œ/. A *Praat* [5] script was used for automatically extracting the F1-F2-F3 values at the midpoint of each vowel (in order to minimize coarticulation effects), using the Burg algorithm as implemented in *Praat*. The amplitude peaks were detected in a band lower than 5kHz for males, and lower than 5.5kHz for females. A filter (adapted from [13]) was used in order to exclude all vowels with aberrant formant values, which were likely to be erroneous formant detections. Formant values were then normalized *via* the Lobanov approach [2, 16]. Additionally, we extracted vowel durations.

Three metrics were calculated for analysing the prosodic strengthening on vowel quality: (i) the Convex Hull Area (CHA) of mean vowel values in the F1/F2 and F2/F3 charts; (ii) Euclidean Distances (ED) in the F1/F2 chart from the Gravity Centre to peripheral vowels /i, a, u/ following [13]; (iii) vowel durations.

3. RESULTS

Different statistical analyses were performed with linear mixed-effects models using the *lme* 4.1 [3] and *lmerTest* [17] packages on *R*. We assessed the contribution of fixed factors and their interactions with likelihood-ratio tests between full and reduced models. Random intercepts for participants were estimated in all models. Post-hoc comparisons with Bonferroni corrections were performed with the *lsmeans* package [21].

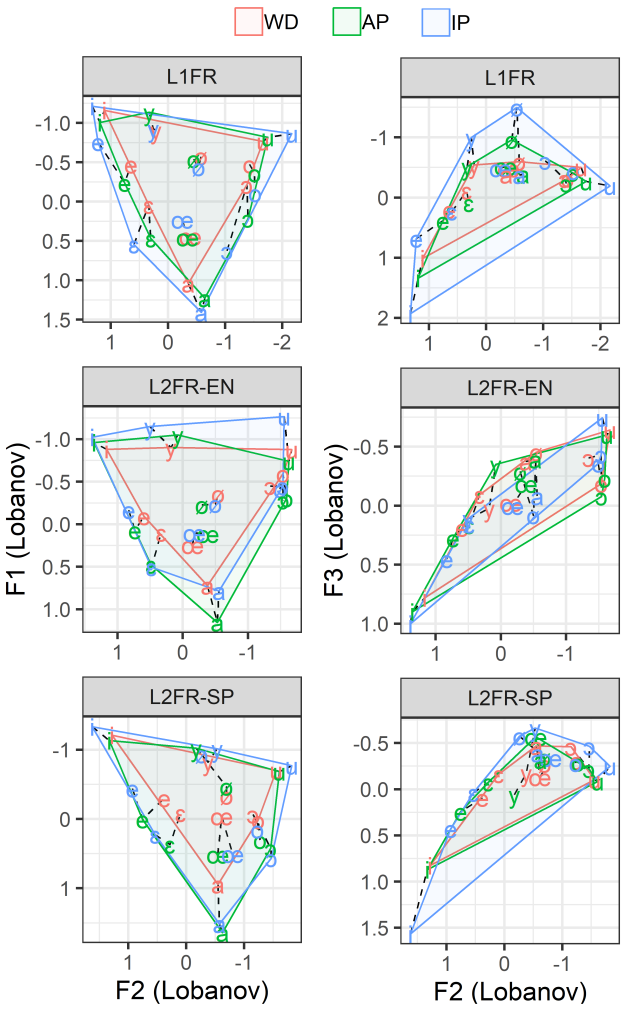
3.1. Prosodic effects on Vowel Quality

After the exclusion of vowels with aberrant formant values, we computed CHA on the remaining 12,383 vowels. The values for each prosodic position (WD, AP, IP) and group (L1FR, L2FR-SP, L2FR-EN) are shown in Table 2.

Table 2: Convex Hull Areas according to the prosodic positions and groups.

V Space	Group	WD	<	AP	<	IP
F1 / F2	L1FR	2.90	<	3.98	<	5.04
	L2FR-SP	2.70	<	4.50	<	4.94
	L2FR-EN	2.53	<	3.86	<	4.03
F2 / F3	L1FR	1.62	<	2.62	<	5.42
	L2FR-SP	1.23	<	1.45	<	2.52
	L2FR-EN	1.31	<	1.64	>	1.06

Figure 1: Convex Hull Areas ~ F1/F2 & F2/F3 vowel charts, prosodic positions & groups

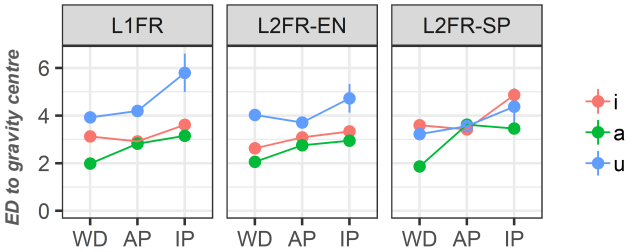


The vowel space in our data of L1 French increases by 37% from WD to AP, and by 26% from AP to IP. This pattern confirms what has been reported by [13]: the acoustic expansion of native French vowels follows the prosodic hierarchy. As for non-native French data, the output of our metrics suggests that vowel space expansion is greater in the strong prosodic positions (AP/IP) than in WD. However, the vowel space expansion in L2 French does not reflect the prosodic hierarchy: in the F1/F2 chart, prosodic strengthening seems to have stronger effects in L2 French between WD and AP than between AP and IP. In fact, vowel space increases from WD to AP by 66% and 52% in L2FR-SP and L2FR-EN respectively, but only by 37% in L1FR. Moreover, the increase of vowel space between AP and IP is lower in learners' productions (+9% for L2FR-ES, +4% for L2FR-EN) than in L1FR (+26%). This can be seen in the left column of Figure 1: vowel areas increase over the three prosodic positions in L1FR, while vowel areas for the L2FR-SP and L2FR-EN groups are virtually unchanged between AP and IP.

With regard to F2/F3 vowel charts in L1FR, vowel space increases across the three prosodic positions (+61% for WD > AP and +106% for AP > IP). In the case of the L2FR-SP group, WD and AP differ by 57%, but only by 9% between AP and IP. For productions of the L2FR-EN group, the vowel area increases by +8% from WD to AP and decreases by -54% from AP to IP.

The second question we address in this study is whether the enhancement of three peripheral vowels depends on the prosodic position. Figure 2 illustrates the ED from the Gravity Centre to each of the three peripheral vowels /i, a, u/ (analysis carried out on 5,399 tokens). We built a mixed-effects model evaluating the effects of VOWEL, GROUP and PROSODIC POSITION on the ED, with PARTICIPANT as a random effect. We find a significant main effect of these three factors on ED and a significant interaction of GROUP*PROSODIC POSITION (χ^2 (8) = 331.12, p < .0001). These results confirm findings for CHA: the effects of prosodic position on ED differ across groups and across prosodic positions. Bonferroni adjusted p-values show that EDs increase as a function of the level of the prosodic hierarchy for the L1FR and L2FR-SP groups: WD > AP > IP (all p-values < .01). Yet, differences of ED between AP and IP do not reach significance for the L2FR-EN group (p > .05). This suggests that L2 French vowels produced by English learners display similar vowel expansion for AP and IP.

Figure 2: Euclidean Distances (ED) ~ prosodic positions, groups & vowels with 95% CI



In Figure 2 we observe that L1 French vowels /u, a/ expand as the prosodic hierarchy increases (all p-values < .0001), but not /i/: for this vowel, the ED

differences are significant only between AP and IP ($p < .0001$), confirming claims by [13] that acoustic patterns of French /i/ are similar between WD and AP (this vowel seems to be more resistant to prosodic strengthening).

As for learners, we observe different scenarios. For Spanish learners, only /u/ increases significantly across the three prosodic positions ($p < .0001$), while /i/ only increases from AP to IP ($p < .0001$) and /a/ only from WD to AP ($p < .0001$). For British learners, /u/ differs significantly across the three prosodic positions, while /i, a/ increase only from WD to AP (all p-values < .001), but not from AP to IP (all p-values > .05).

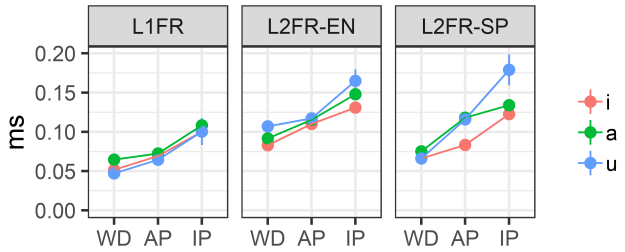
3.2. Prosodic effects on Vowel Durations

The final question addressed in this study is whether the effects of prosodic position are observed on durations of L2 French vowels. As pointed by [10, 13], French vowels are lengthened when they are accented or associated to final melodic contours. According to these authors, higher prosodic prominence is reflected by vowel durations, other than vowel space expansion.

In order to evaluate whether this effect is present in L2 data, we built a mixed-effects model evaluating the effects of GROUP, PROSODIC POSITION and VOWEL on vowel durations. PARTICIPANT was entered as a random effect. The statistical analysis shows effects of the three fixed factors on vowel durations (χ^2 (8) =1259.5, $p < .0001$).

Post-hoc comparisons with Bonferroni's correction indicate that vowel durations are longer in higher prosodic positions in L2 French (all p-values < .01). Figure 3 illustrates vowel duration differences across the three prosodic positions. It can be observed that, in contrast to ED (see Figure 2), vowel durations of both L2 groups are affected by the prosodic hierarchy, similar to L1 French.

Figure 3: Vowel durations ~ prosodic positions, groups & vowels with 95% CI



4. DISCUSSION & CONCLUSION

Our first metric (Convex Hull Area) suggests that prosodic positions condition the vowel space in L2 French. Yet, the prosodic hierarchy is not reflected in learners' productions, contrary to L1 French: L2 vowel spaces do not differ between AP and IP, but only between WD and AP/IP. The second metric (Euclidean distances) is mainly in line with this result and gives additional insight: /i, u/ produced by Spanish learners seem to reflect the canonical prosodic strengthening found in the target language, but not /a/. For British learners, /u/ expands as a function of its position in the prosodic hierarchy, but /i, a/ do not. Clearly, not all vowels are acoustically expanded following the prosodic hierarchy in L2 French.

Various explanations can be conjured for such observations. Firstly, prosodic strengthening may stem from a positive L1 transfer in the case of English learners, since [6, 7] have shown that vowel expansion is affected by prosodic strengthening in English. However, [6] also claims that the degree of vowel expansion reflects the level of prosodic prominence: L1 English vowels /i, ɑ/ follow the prosodic hierarchy [6]. In our data, L2 French vowels /i, a/ produced by English learners do not expand from AP to IP. The postulation of a positive L1 transfer cannot account for such observations.

Similarly, the postulation of a negative L1 transfer is also not satisfactory for the explanation of patterns observed for Spanish learners. The presence/absence of pitch accents does not cause vowel expansion in L1 Spanish [19, 20], but our results show an expansion of /i, u/ in L2 French by Spanish learners, which follows the prosodic hierarchy of the target language.

We propose an alternative explanation for such results. Firstly, prosodic strengthening in L2 may be the result of extreme hyper-articulation [4]: learners, regardless their L1, try to re-enhance phonological features of the L2 and hyper-articulate vowels in any strong prosodic position, without differentiating AP and IP. In other words, AP and IP could serve as the primary or default location where learners enhance vowels in an L2. This could explain why vowel spaces do not expand between AP and IP positions in learners' productions, and why only some of the three peripheral vowels expand as a function of the prosodic hierarchy. This speculation will of course need to be tested on a larger data set (including all French vowels) as well as in IP-initial positions.

Finally, vowel durations show that all groups produce lengthened vowels as a function of the prosodic position: the higher the prosodic domain, the longer the vowels. This seems to suggest that the acquisition of temporal patterns in correspondence to prosodic strengthening are less problematic for L2 French learners than the acquisition of differences in vowel expansion.

5. REFERENCES

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6. AKNOWLEDGEMENTS

This work is partially supported by a public grant overseen by the French National Research Agency (ANR) as part of the program *Investissements d'Avenir*, Labex EFL, (reference ANR-10-LABX).