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# ROUNDING AND HEIGHT CONTRASTS AT THE BEGINNING OF DIFFERENT PROSODIC CONSTITUENTS IN FRENCH

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## ABSTRACT

Variations in the acoustic manifestations of the rounding and height contrasts in French vowels are investigated in different prosodic positions. Four speakers produced sentences containing the vowels /i, e, a, y, ø/ at the beginning of different prosodic constituents: Intonational Phrase, Accentual Phrase and Word. Acoustic cues for the rounding contrast (F2, F3, F3-F2) and for the vowel height contrast (F1) are found to be enhanced in Intonational Phrase initial positions.

**Keywords:** segmental contrast, prosody, French.

## 1. INTRODUCTION

This study investigates the influence of prosodic positions on the acoustic realization of speech sounds. Variation depending on prosodic position has been described in different languages and for different types of segments. So far, variation at the left edge of a constituent (so-called initial strengthening) has been observed mostly on consonants for lingual, glottal or jaw articulation [2], [7]. Variation in the realization of vowels located close to prosodic boundaries has mainly been studied for domain-final vowels, or for vowels in CV initial syllables of prosodic constituents to question the domain of initial strengthening [3], [4], [7].

In the present study, acoustic properties of vowels in absolute initial position (post-boundary) are compared in different prosodic domains. The question of the nature of the strengthening process is addressed by testing whether variation affects the acoustic cues of the phonological contrast between round and unrounded vowels and between vowels of different height in French. Fougeron [8] showed that the vowel /i/ in the /p#ip/ sequence (where # stands for a prosodic boundary) has more linguopalatal contact (i.e. is more closed) following higher prosodic boundaries. This result challenges the view that prosodically-driven variations increase the sonority of vowels (*sonority*

*expansion hypothesis* [1], [3], [6]). It rather supports an enhancement of contrastive attributes in strong positions, as predicted by the *local hyperarticulation hypothesis* (e.g. [4], [6]). Predictions of these two competing hypotheses will be further compared here by testing vowels contrasting in rounding (/i-y/, /e- ø/) and in vowel height (/i-e-a/).

## MATERIAL AND METHODS

### 1.1. Speech material and speakers

Acoustic realization of the vowels /i, e, a, y, ø/ are studied in sentences cueing different prosodic phrasing. As illustrated in **Table 1**, the test vowels ( $V_2$ ) appear in a  $V_1C_1\#V_2C_2$  sequence where  $V_2C_2$  are the beginning of a (fake) first name, and # holds for either an Intonational Phrase (IP), an Accentual Phrase (AP), or a Word (Wd) boundary. Pre-boundary context ( $V_1C_1$ ) and following consonant ( $C_2$ ) are kept constant ( $V_1=/i/$ ,  $C_1$  &  $C_2=/p/$ ). Four native French female speakers (aged 25 to 40 years, with no identifiable regional accent) read the sentences in a random order. Each sentence was read twice consecutively at a comfortable speech rate and the entire list was read eight times, for a total of 1075 repetitions. The first author coded prosodic phrasing of each rendition, and for 180 utterances for which the phrasing was not obvious, the judgment of 3 expert phoneticians was used. 50 sentences were discarded due to lack of inter-judge agreement, leaving 1025 tokens to be considered in this study.

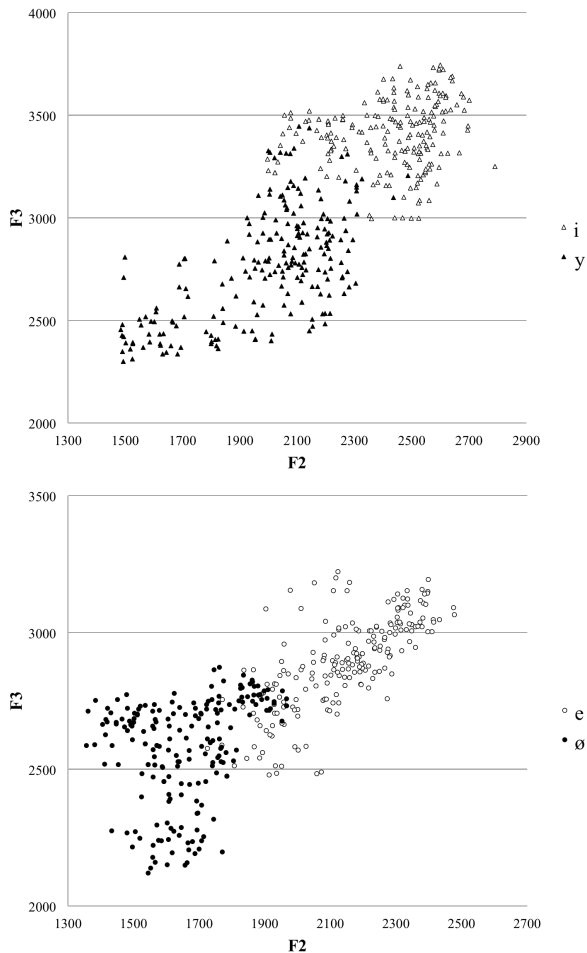
**Table 1:** Sample sentences containing the sequence  $V_1C_1\#V_2C_2$  with different prosodic boundaries (#: Intonational Phrase, Accentual Phrase, Word)

IP	Pour le roi Philippe, <b>I</b> picaz et Larsen se battent comme des dieux. ( <i>For king P., Ipicaz and Larsen fight as gods</i> ).
AP	Oupoulo, Philippe, <b>I</b> picaz et David sont comme des frères. ( <i>Oupoulo, Philippe, Ipicaz and David are like brothers</i> ).
Wd	Dalida et <b>L</b> ippe- <b>I</b> picaz sortent un tube d'enfer. ( <i>Dalida and Lippe-Ipicaz launch a hell of a hit</i> ).

## 2. Rounding contrast

### 2.1. Acoustic cues of the rounding contrast

As expected and illustrated in **Figure 1**, acoustic differences between front rounded /y, ø/ and unrounded /i, e/ vowels are found in F3 and F2.



**Figure 1:** Distribution of the vowels /i, y/ (top), /e, ø/ (bottom) in the F2/F3 dimensions (all speakers and all prosodic conditions confounded).

All prosodic positions and all speakers pooled, the contrast between /i/ and /y/ is cued by a lower F2 ( $F(1,398)=1125$ ,  $p<.0001$ ) and a lower F3 ( $F(1,398)=1483$ ,  $p<.0001$ ) for the rounded vowel /y/. Similarly, the contrast between /e/ and /ø/ is also cued by a lower F2 ( $F(1,401)=1527$ ,  $p<.0001$ ), a lower F3 ( $F(1,401)=737$ ,  $p<.0001$ ) for /ø/. In terms of F3-F2 distance, /y/ show more compacity than /i/ ( $F(1,398)=1483$ ,  $p<.0001$ ). This compacity between F3-F2 is not found for the other rounded vowel /ø/, which has a rather central F2 and thus a larger F3-F2 distance than /e/ ( $F(1,401)=190$ ,  $p<.0001$ ).

These acoustic differences are found to be all speaker-dependent (all interactions between vowel type and speakers at  $p<.0001$ ). Subsequent analyses by speaker show that effect sizes vary, but that all speakers mark the distinctions found for F2 and F3. However, for the F3-F2 dimension, the distinction between /i/ and /y/ holds for 2 speakers only (S2, S3) and the distinction between /e/ and /ø/ holds for 3 speakers (all except S3).

### 2.2. Effect of prosodic position

The effect of ‘Prosodic Position’ is tested for each vowel (all speakers pooled) on the three acoustic dimensions found to be linked to the rounding contrast (F2, F3, F3-F2) with an ANOVA with the prosodic position as fixed factor. Results are presented in Table 2 and illustrated in **Figure 2** for each speaker individually.

**Table 2:** Main effect of ‘prosodic position’ and Fisher post-hoc comparisons on F2, F3 and F2-F3 values for each vowel. Significance levels: \*\* $p<.0001$ , \* $p<.05$ , ns:non significant.

	F2	F3	F3-F2
/i/	$F(2,182)=4$ ns	$F(2,182)=32$ ** IP>*AP,Wd	$F(2,182)=36$ ** IP>*AP,Wd
/e/	$F(2,195)=13$ * IP>*AP,W	$F(2,195)=38$ ** IP>*AP>*Wd	$F(2,195)=6$ * IP>*AP,Wd
/y/	$F(2,200)=1$ ns	$F(2,200)=11$ ** IP<*AP,Wd	$F(2,200)=13$ ** IP<*AP,Wd
/ø/	$F(2,190)=0$ ns IP>*AP,W	$F(2,190)=3$ ns	$F(2,190)=7$ ** IP,AP<*Wd

Over all speakers, the effect of prosodic position on the realization of domain initial vowels varies according to the vowel, the acoustic dimensions affected and the number of position distinguished.

Distinctions are found to be more frequent and systematic between the IP initial position and the two lowest positions in the hierarchy, AP and Wd (except for F3-F2, for /ø/ where IP=AP). Vowels in AP initial position are generally similar to that in Wd initial position (except for F3 /e/ where the only 3 way distinction is found IP>AP>Wd).

Variations can be observed according to vowel category. Recall that the unrounded vowels /i/ and /e/ differ from their rounded counterparts by a higher F2 and a higher F3. Prosodic position is found to have an effect on these dimensions. Compared to AP and Wd-initial positions, IP-initial /i/s have a higher F3; and IP-initial /e/s have a higher F2 and F3. In terms of F3-F2, both unrounded vowels have a larger F3-F2 distance in

IP initial position (the increase in F3 being greater than the change in F2).

These effects of prosodic positions on the realization of the two unrounded vowels vary according to speaker (all speaker\*position interactions significant at  $p < .01$ ). As illustrated on **Figure 2**, for /i/ the effects on F3 and F3-F2 hold for all speakers except S2. S3 also shows a higher F2 in IP-initial position than in AP/Wd. For /e/, higher F2 and F3 in IP-initial position is found for all speakers, while a larger F3-F2 distance holds for all speaker except S2.

As far as the rounded vowels are concerned, the effects of prosodic position are less consistent. All speakers pooled, /y/ is found to have a lower F3 and a smaller F3-F2 distance when initial in IP compared to AP/Wd. /ø/ has a higher F2 in IP initial position compared to AP/Wd and a smaller F3-F2 distances when initial in IP and AP compared to Wd. No effect is found on F3. Variation in F2 for this vowel could be linked to rounding but also to variation in tongue fronting.

For the rounded vowels, interactions between the factors position and speaker are also found (all at  $p < .01$ ). Examination of the patterns by speakers (see **Figure 2**) shows that prosodic position effects on rounded vowels are less systematic across speakers, and are shown principally by speakers S1 and S4. For /y/, the effect on F3 holds only for S4, and the effect on F3-F2 holds for S1 and S4. For /ø/, the effects on F2 and F3-F2 hold for S1 and S4 (S3 showing also a distinction AP < \*Wd for F3-F2)

### 3. Vowel height contrast

#### 3.1. Acoustic differences between /i, e, a/

As expected, all speakers and all positions pooled, the vowel height contrast between /i, e, a/ is cued by variation in F1 ( $F(2,599)=1976, p < .0001$ ). Post-hoc comparisons (Fisher's test) show a three-way distinction with an increase of F1 from /i/ to /e/ to /a/ ( $p < .0001$ ). While the size of the differences vary according to speaker (all interactions at  $p < .0001$ ), all speakers show the same patterns, except for S4 who do not distinguish /i/ and /e/ in terms of F1.

#### 3.2. Effect of prosodic position

The effect of the prosodic position was tested for each vowel on F1 values. All speakers pooled, an effect of position is found only for the open vowel /a/ ( $F(2,198)=82, p < .0001$ ). Both all speakers

confronted, and for all speaker tested individually, /a/ in IP-initial position have a higher F1 than in both AP and Wd initial positions.

An effect of position is also found for speaker S4 for /e/ ( $F(2,41)=4, p=0.02$ ), with IP-initial /e/ having a higher F1 (vs. AP/Wd). A surprising effect is observed for speaker S3 for /i/ with a higher F1 in IP and Wd initial positions compared to AP ( $F(2,42)=9, p < .001$ ). However, as illustrated on **Figure 3**, differences in Hz are rather small.

## 4. Conclusions

In this study, the effect of prosodic position on the realization of initial vowels is tested on acoustic features related to vowel contrasts in French. For rounded and unrounded vowels, variations in F2, F3, and F3-F2 are observed. For vowels contrasting in three degrees of aperture, variations in F1 are tested.

Results show that the prosodic position of the vowels can affect these acoustic dimensions. However, as observed previously in the literature (e.g. [2][7]), among the positions tested distinctions are more frequent and follow a more regular trend between the highest prosodic domain (here Intonational Phrase) on one side, and the lowest domains (here Accentual Phrase and Word) on the other side. Speaker differences are also frequently observed, some speakers showing more effects (e.g. S1 and S4 in 2.2) than others (e.g. S2 in 2.2).

Interestingly, our results show that the direction of the variations observed in IP initial positions compared to AP and Wd initial positions depend on vowel category. For the unrounded vowels /i/ and /e/, acoustic cues marking the contrast with their rounded counterparts are enhanced. These effects hold for at least three, if not all four speakers, depending on the comparisons. For the rounded vowels, there is also a global trend for an enhancement of the acoustic manifestation of rounding in IP initial position, but two speakers mainly support these effects. For the open vowel /a/, there is also an enhancement of the acoustic cue of vowel height (F1).

Globally, when an effect of prosodic position is found, /i, e/ are acoustically more 'unrounded-like', /y, ø/ are more 'rounded-like', and /a/ is more 'open-like' when they are in initial position of the the highest prosodic domain (IP). These results can be discussed in the light of the two hypotheses proposed in the literature to explain the nature of

the influence of prosody on segmental realization. According to the *sonority expansion hypothesis* [1], segments in strong positions are expected to display an increase in their intrinsic sonority. The variations we observed in F2, F3, and F3-F2 can not be related to a sonority expansion. They rather support the predictions of *local hyperarticulation hypothesis* [4], according to which the contrastive characteristics of the unrounded and rounded vowels are enhanced by a local hyperarticulation of the gestures toward their presumed targets.

Concerning the effects found for /a/, the increase of F1 in IP initial position found for all speakers can be interpreted either as an increase of sonority, or as a hyperarticulation of the low target of the tongue. In order to distinguish these two interpretations, we were expected to find an effect on the F1 of the closed vowel /i/ or of the mid-closed vowel /e/. Only one of the four speaker shows an effect for /i/, but the trend does not follow the prosodic hierarchy (IP,Wd>AP) and is hard to interpret. An effect is also found for one speaker for /e/, suggesting an increase in sonority. Further interpretation of these last results is not reasonable at this stage. This study needs to be completed by the observation of other French vowels (examination of the mid-open vowel /ɛ/ and back vowels is underway).

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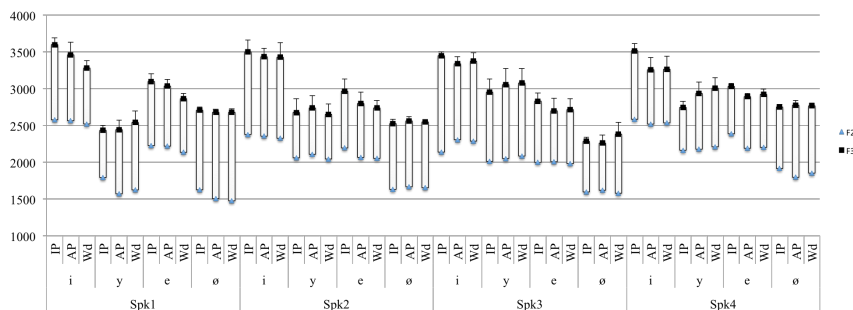


Figure 2: F2, F3 and F3-F2 values for /i/, /y/, /e/ and /ø/ for each speakers in IP, AP and Wd prosodic conditions (Hz).

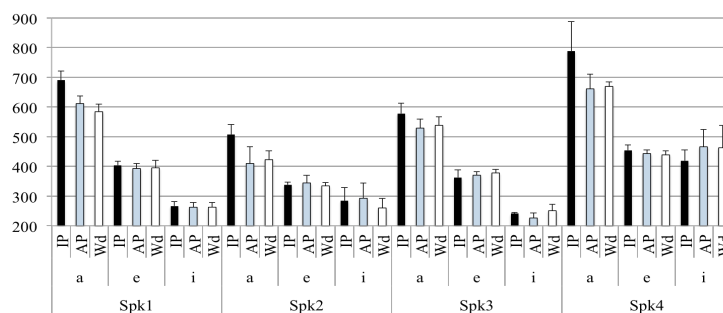


Figure 3: F1 values for /a/, /e/ and /i/ for all speakers in IP, AP and Wd prosodic conditions (Hz).