

target syllable in (3b) has no F0 rise nor lengthening, being unaccented position; (iii) the target syllable in (3c) has an F0 rise accompanied by lengthening, realizing a demarcating Prosodic Phrase accent which marks a boundary of this larger prosodic group.

Besides the position in the sentence, the syllable number of the noun and the structure of the target syllable (open / closed) are controlled as follows:

Table 1: Target syllables by syllable number of the noun and by the syllable structure

syllable number	open syllable	closed syllable
1	ʃa	sɔl
2	ti	nal
3	la	val
4	ka	nal

The onset consonants and the nuclear vowels are not totally controlled, but the coda is always [l]. The phoneme number of the whole sentence and of the <article+noun+adjective> portion is equalized for each set of (3a)-(3c) to attenuate the possible sentence-length effect. However, the interspeaker variation of 1-3 phonemes is observed depending on the realization or not of final schwa or liaison. In total, 24 sentence-types are analyzed.

2.2. Subjects and Procedure

4 speakers, 1 male (SP1 from Tour) and 3 females (SP2 and SP3 from Provence, and SP4 from Lorraine) participated in the experiment. None of them had a strong regional accent. The sentences are randomized and the participants read the corpus 12 times. 10 cases other than the shortest and the longest ones are retained for analysis. In total, 320 cases for (3b) and (3c) and 319 for (3a) are analyzed, 1 case of (3a) with a pause being excluded. The recordings are digitized at 16kHz and the target syllables are labeled phonemically by hand on PRAAT. Two parameters are examined: F0 and duration. The whole sentence duration is also measured to check that the speech rate remains constant. For F0, the tonal patterns of <article+noun+adjective> part are labeled using L, Hi, H1, and H2. H1 is assigned to the target syllable when it accompanies F0 rise or peak. H2 is labeled to the adjective-final syllable when it accompanies an F0 rise. Hi indicates the initial rise or peak on the first syllable(s) of nouns or adjectives. The syllables where the pitch is low or going down are represented by L. Figure 1 shows an example of tonal pattern [LLH1LLH2] where both the target syllable on noun and the final syllable of adjective have an F0 rise with no initial rise.

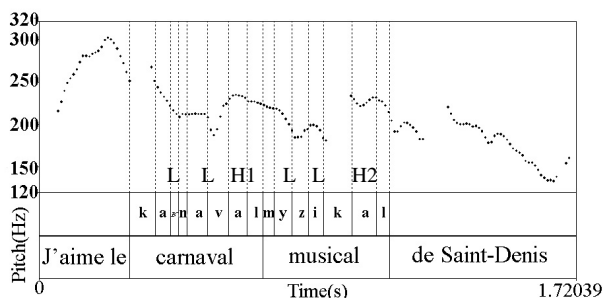


Figure 1: Example of the tonal pattern [LLH1LLH2] on the noun phrase "le carnaval musical (the music carnival)"

For sentences (3a), only the cases where the target syllable is labeled H1, i.e. the ones which matched our hypothesis, were retained for further duration analysis. That is, the vowel duration of target syllables with H1 in (3a) is measured and compared statistically with the vowel duration of target syllables in (3b) and (3c). All the target syllables in (3b) have no F0 rise, and on the contrary, all of those in (3c) are realized with the expected F0 rise. In this paper we don't treat the tonal difference between perceptual "rise" and "peak" which will be examined in our further studies.

3. Results

3.1. Tonal pattern

On the target syllables in (3a), the expected F0 rise is realized on 121 of 319 cases, i.e. 37.9% of all the realizations by 4 speakers. The interspeaker variation is observed for the frequency of H1: 32.9 % (SP1), 68.8% (SP2), 20.0% (SP3), and 30.0% (SP4). Its frequency varies also by syllable number of the noun : while the nouns of 2 and 3 syllables accompany an F0 rise on final syllable for more than half cases (67.1% and 53.7% respectively), those of 1 and 4 syllables realized less final F0 rises (16.3% and 15.0% respectively). Table 2 represents the distribution of tonal patterns for the cases with H1 (final F0 rise on the noun) in (3a). The tonal patterns can be categorized by the occurrence of Hi on the noun or/and adjective. Table 1 shows that the recurrence of L and H (LH1LH2 or LHiLH1LH2) is preferred to the collision of H tone (HiH1 or H1Hi), being realized on 83.5% of all the cases. Hi appears mainly on the adjective (20/23 cases), indicating the beginning of the 2nd element of the noun phrase. Hi on the 1st element appears only on the noun of more than 2 syllables.

Table 2: Distribution of tonal patterns on <noun + adj.> with final F0 rise on noun (number in brackets: percentage; contiguous Ls are indicated by a single L)

	without Hi on Adj.	with Hi on Adj.	total
without Hi on N	LH1LH2 98 (81.0)	LH1HiLH2 19 (15.7)	117 (96.7)
with Hi on N	LHiLH1LH2 3 (2.5)	LHiLH1HiLH2 1 (0.8)	4 (3.3)
total	101 (83.5)	20 (16.5)	121 (100)

We also labeled the tonal patterns of the cases without H1 (62,1% of 319 cases) which are excluded from the duration analysis. Table 3 represents the observed tonal patterns by noun syllable number. The noun-final L tone is indicated separately from the next L on the beginning of the adjective.

Table 3: Distribution of tonal patterns on <noun + adj.> without final F0 rise on noun

Tonal pattern		syllable number of N				total
Art.+N	Adj.	1	2	3	4	
L	LH2	13	16	5	8	42
LHiL	LH2			6		6
L	HiLH2	43		3	25	71
L	HiLH2	8	9		15	32
L	HiH2	3				3
L	LHiL		1			1
LHiL	HiLH2			23	20	43
total		67	26	37	68	198

Also on the cases without final F0 rise (H1) on the noun, the same tendency to prefer the recurring 'LH' is observed, the collision of H1 and H2 appearing on 32 of 198 (16.2%) cases. The most frequent pattern (35.9%) was L|HiLH2 where the two intervals between two H tones are equilibrated in comparison with the other patterns. As for the next frequent pattern L|LH2 (21.2%), it appears more frequently on the nouns with less number of syllables (1 or 2) where the sequence of L does not exceed 3 syllables. Generally, it can be said that the speakers prefer the recurrence of the elemental rhythmic pattern 'LH' where H was realized as either initial Hi or final H1.

3.2. Duration of target syllables

Here we examine the durational properties of the noun-final H1 tones (from (3a)) in comparison with phrase-final tones (from (3b)) as well as with word-median unaccented syllables (from (3c)). We expect that it does not accompany lengthening as the boundary tones do. Therefore, only the cases with H1 accent (37.9% of (3a)) will be treated in the further analysis.

3.2.1. Speech rate control

Preliminarily, the possible inter- and intra-speaker variation of speech rate is examined. Table 4 shows the average speech rate (ms per phoneme) by speaker and by sentence type.

Table 4: Average speech rate by speaker and by sentence type (ms per phoneme)

	sentence(3a)	sentence(3b)	sentence(3c)	Average
SP1	68.8	70.4	66.4	68.5
SP2	66.6	68.0	66.0	66.9
SP3	68.6	70.6	67.1	68.8
SP4	68.5	70.2	68.2	68.9

As the table shows, the inter- and intra- speaker variation of average speech rate does not exceed 5 ms. It was also observed that the maximum difference throughout the corpus does not exceed 11 ms. We can conclude that the speech rate is closely similar between speakers or sentences, variation being negligible in our corpus.

3.2.2. General tendency

ANOVA was carried out with 4 factors: Prosodic Position of the target syllable ((3a)-(3c)), Speakers (1-4), Syllable Number of the noun (1-4) and Syllable Structure (open or closed). The results of the 4-way ANOVA show that, at a 5% significant level, all the factors and interactions are significant ($p < 0.0001$ except $p < 0.008$ for Syllable Structure) except the Speaker-Syllable Number interaction ($p = 0.604$). We examine below the effect of the Position factor and its interactions with three other factors, by means of Tamhane and of Fischer's PLSD post-hoc tests (with a significant level at 5%).

3.2.3. Main effect of the Prosodic Position

Henceforth, the positions (3a), (3b) and (3c) of target vowels are called respectively WfA (Word-final Accent), UNA (unaccented) and PfA (Phrase-Final Accent). The post-hoc tests on vowel duration show that vowels in WfA position are not significantly lengthened compared with those in UNA position ($p = 0.499$), PfA differing significantly ($p < 0.0001$) from the two other positions (Figure 2). In other words, a

word-final F0 rise can appear without lengthening.

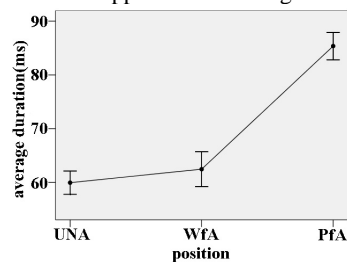


Figure 2: Average vowel duration of three positions (error bar: 95% confidence intervals)

3.2.4. Interactions of Position with the other factors

The closed syllables do not have exactly the same behavior as the open ones. WfA and PfA are significantly different with the open syllables ($p < 0.0001$) as well as with the closed ones ($p < 0.0001$), but their difference is near 30 ms for the open syllables while it is less than 15 ms for the closed syllables (Figure 3). The open and closed syllables also differ from each other in that WfA is not distinguished significantly from UNA for the open syllables ($p = 0.997$) while it is for the closed syllables ($p < 0.0001$). However, the difference between WfA and UNA remains very small, that is less than 10 ms.

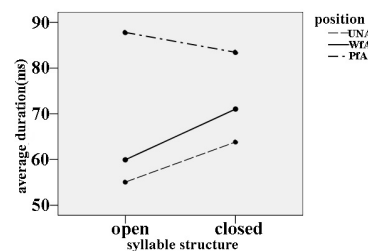


Figure 3: Average vowel duration of three positions by syllable structure

The investigation of standardized duration (by z -transform, see [7]) of the sub-syllabic components enhances an important interaction of the syllable structure with the prosodic positions (Figure 4). The distribution of lengthening among the syllabic components seems to be modified by the [l] syllable-closing.

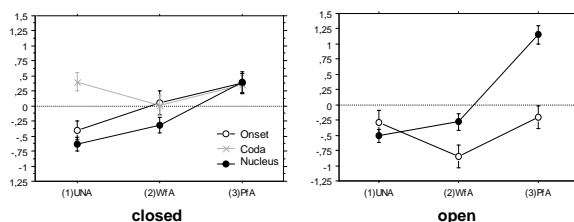


Figure 4 Average standardized duration (y axis) of onset, nucleus and coda by positions for closed and open syllables

Thus in an unexpected way, at prosodic boundary (PfA), vowel lengthening is reduced and the coda duration does not increase at all. Instead, a compensatory lengthening of the onset consonant seems to take part in syllable-final lengthening. Concerning WfA, the onset duration is affected by syllable structure: with regard to the unaccented position, it is significantly reduced in open syllables while significantly increased in closed ones ($p < 0.0001$ for both). Nevertheless,

both of these opposite differences do not exceed on average about 10 ms. Besides, regarding the onset and nucleus duration for closed syllables, WfA might be considered as an intermediate level between UNA and PfA. These results do not match the patterns of sub-syllabic duration drawn by previous studies on accentual and boundary lengthening in French [8]. Furthermore, they are largely weakened when the interaction of the other factors are considered.

The vowel duration also varies by the syllable number of the noun (Figure 5). The post-hoc tests show that the difference between WfA and PfA is always significant and generally longer than 20 ms ($p < 0.0001$). The increase of syllable number of the noun from 1 to 4 does not seem to affect differently the durational property related to these three prosodic positions: WfA and PfA remain two different phonological categories. WfA is not statistically distinguished from UNA, except with the three syllable nouns. However, we cannot explain this only difference.

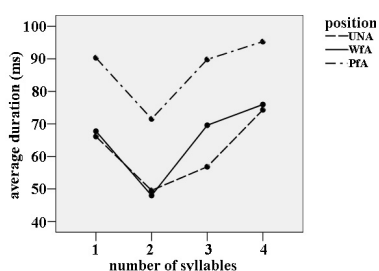


Figure 5: Average vowel duration of three positions by syllable number of the noun (Note that the shorter vowel for two-syllable nouns in all positions is due to the intrinsic shorter duration of [i] used in only this context.)

Finally, we also observed a speaker variation where the general vowel duration of SP1 is significantly different from those of SP2 and SP4 ($p < 0.0001$). Figure 6 shows that the general inter-speaker variation is mainly due to that of PfA, for which the same significant differences as the general variation are observed. There is no significant inter-speaker difference for vowel duration in WfA. As for UNA, a significant difference is observed only between SP1 and SP4 ($p < 0.0001$). The non-significance of inter-speaker difference for WfA seems to indicate that F0 rise without lengthening is a prosodic property of this position. In contrast, the important variability at PfA suggests that speakers may realize different kinds of prosodic boundary, i.e. either Prosodic Phrase or Intonational Phrase [2], or may use differently tonal and temporal features to signal the same boundary level: SP1, for example, uses lengthening much less than the other speakers.

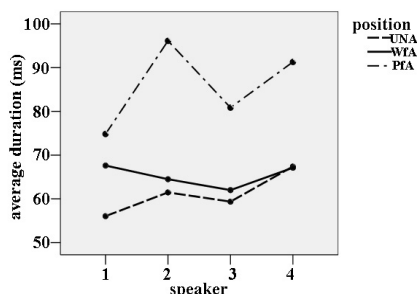


Figure 6: Average vowel duration of three positions by 4 speakers

4. Discussion and Conclusion

Overall, the results seem to attest the occurrence of final F0 rise without lengthening on content words, which could be called a 'final rhythmic accent' in the sense that it does not demarcate a prosodic boundary but rather serves to form the elemental rhythmic pattern inside the boundaries. No strong interactions of the syllable number of accented words or of the speaker variability on vowel duration are observed which importantly weaken this main result. Nevertheless, complex crossing effects of the syllable structure on sub-syllabic durations blur this conclusion. Further investigations on sub-syllabic temporal pattern seems to be needed to test if WfA could be distinguished from PfA, UNA and/or word-initial accent, as previous studies let us envisage.

Besides, it is observed in our corpus that the recurrence of 'LH' is preferred and that the final F0 rise, in concurrence with the initial F0 rise, participated in the realization of this recurring pattern. This final F0 rise without lengthening differs from both Hi and H* in /LHiLH*/ or medial H by Jun & Fougeron [4][5]. According to Jun & Fougeron [5], Hi occurs on 'some initial (i.e. 1st or 2nd, and rarely the 3rd)' syllable of the AP-initial content word and marks the initial boundary of an AP together with the preceding L tone. However, it is difficult to consider the final F0 rise as a delayed Hi which happens to fall on the final syllable when the target syllable is no longer at the initial position of an AP, as in the cases with the nouns of 3 or 4 syllables. Furthermore, the co-occurrence of the initial and final rise before the group-final accent are observed ([LHiLH1LH2] and [LHiLH1HiLH2] in Table 2), even if they are rare cases. The final F0 rise without lengthening observed in our corpus also differs from the medial H [5] in that it was realized at the final syllables of content words.

Di Cristo's model [2], which sees the final F0 rise without lengthening as a part of the Tonal Unit, would seem to be better able to integrate this low accent-level. However, it is to be verified if the initial and final F0 rise without lengthening share the same prosodic property as [2] predicts. This point and the possible distinctive temporal infra-syllabic patterns of initial vs final accent inside AP will be the focus of further investigations with the aim of discussing about a hypothetical lowest prosodic constituent (i.e. TU) inside the Prosodic Phrase [2] or Accentual Phrase [4] [5] in French.

5. References

- Delattre, P., 1938. L'accent final en français: accent d'intensité, accent de hauteur, accent de durée. *The French Review*, Vol. 12, No. 2, 141-145.
- Di Cristo A., forthcoming. Regards sur la prosodie du français.
- Garde, P., 1968. *L'accent*. Paris : PUF.
- Jun, S.A.; Fougeron, C., 2000. A phonological model of French intonation. In *Intonation*. A. Botinis (ed.). Dordrecht: Kluwer Academic Pub., 209-242.
- Jun, S.A.; Fougeron, C., 2002. Realization of accentual phrase in French intonation. *Probus* 14, 147-172.
- Rossi, M., 1985. L'intonation et l'organisation de l'énoncé. *Phonetica* 42(2-3),135-153.
- Campbell, N., 1992. Syllable-based segmental duration. In *Talking Machines: Theories, Models and Designs*. G. Bailly et al.(eds), Amsterdam: Elsevier Pub., , 211-224.
- Astésano, C., 2001. *Rythme et accentuation en français*. Paris: L'Harmattan