AN INVESTIGATION OF ARTICULATORY CORRELATES OF THE ACCENTUAL PHRASE IN FRENCH

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ABSTRACT

This study examines the articulatory correlates of a prosodic entity, the Accentual Phrase (AP), based on a linguistic model of French prosody. The AP, features an initial high tone Hi, or the peak of the 'accent secondaire', a final high tone H*, also called the peak of the 'accent primaire', and two low L tones preceding them. Several sentences containing four-syllables target words (APs), were recorded using EMA. Position of the word in the sentence was varied and different speaking conditions were elicited. Displacement, peak velocity and movement duration are analyzed for the vertical position of the tongue-middle. The results suggest that LHi could be related to hyper-articulation of the first or second syllable, and LH* to even stronger hyper-articulation of the last syllable. When contrastive emphasis is present on the AP, the initial hyper-articulation can become as strong as, and even stronger than, the final one.

1. INTRODUCTION

Recent articulatory studies of French prosody at the supraglottal level (e.g. [1]) have dealt with stress in general without consideration of the prosodic structure. Their conclusion is that stressed syllables generally show greater jaw displacement, duration and peak velocities, but not always. This lack of regularity could be due to the fact that different phenomena ('accents primaires', 'secondaires') are examined together. The aim of this paper is to examine the articulatory correlates of a prosodic entity based on a linguistic model of French prosody.

Fougeron & Jun [2,3] proposed a model of French intonation where the lowest tonally-defined level in the prosodic hierarchy is the Accentual Phrase (AP). The AP roughly corresponds to Vaissière's [4] 'prosodic word', Mertens's [5] 'Intonation Group' or Rossi's [6] 'Intonème Mineur'. It has the underlying tonal representation /LHi LH*/, with an initial high tone Hi (also described as the peak of the 'accent secondaire', Pasdeloup [7]), a final high tone H*, realized on the phrase-final full syllable (peak of the 'accent primaire'), and two low L tones realized on the syllable preceding the H-toned syllable. The present study investigates the articulatory characteristics of the AP as defined tonally by Fougeron and Jun.

2. METHOD

2.1. Speech material

The corpus consists of several read sentences, containing 4-syllable target words, where the AP is expected to occur. There are debates about the variation in the location of the 'accent secondaire' (LHi). One possibility to consider is that LHi gets anchored loosely at the left edge, so that variation in locale is just an artifact of tone alignment for unassociated accents. Hi is therefore expected to occur on one of the first two syllables of the target words, and H* on the last syllable.

The articulatory characteristics of the 4 syllables in the target words are analyzed and compared as a function of their positions within the word. The expectation is to match the tonal peaks on syllables 1 (or 2) and 4. The corpus was designed so that acoustic and articulatory analyses were made easier. That is, to facilitate F0 tracking, only sonorants were used, and to have clear tongue movements, syllables containing vowels /i/ and /a/, which correspond to extreme tongue displacements in the horizontal and vertical dimensions, were selected. The following target words were chosen: "l'anonymat" (/la-no-ni-ma/, anonymity), "l'anomala" (/la-no-ma-la/, beetle), "l'éliminé" (/le-li-mi-ne/, eliminated), "l'illuminé" (/li-ly-mi-ne/, crank). The choice of the syllables to be compared was based on the need for similar phonetic contexts in order to have similar coarticulation phenomena. Coarticulation affects the articulatory realization of a given syllable and could alter the AP articulatory characteristics. The following comparisons were thus carried out:

/ma/ as σ3 in /la-no-ma-la/ and σ4 in /la-no-ni-ma/.

/la/ as σ1 and σ4 in /la-no-ma-la/.

/li/ as σ1 in /li-ly-mi-ne/ and σ2 in /le-li-mi-ne/.

Position of the target word in the sentence was also varied (initial, central, final), like for instance :

'L'illuminée a allumé néanmoins le monument.' (Initial).
(The crank has nevertheless lighted the monument.)
'Il a humilié l'illuminée en l'éloignant.' (Central).
(He humiliated the crank by moving her away.)
'L'aumonier a néanmoins éloigné l'illuminée.' (Final).
(The chaplain has nevertheless moved the crank away.)

In the first set of recordings, called the *natural* set, all the sentences were pronounced under 3 conditions: *normal* – where the instruction was to read the sentence at a comfortable rate and articulation – , *clear* – where the instruction was to be clear to the listener, *clearest* – be even clearer.

In the second set, called the *emphasis* set, we tried to elicit contrastive emphasis on the target word. Before each recording, a sentence was played to the subject, where the target word had been replaced by a wrong 4-syllable word. The subjects had to correct the sentence, placing contrastive emphasis on the target word. As the productions were supposed to be clear enough, there wasn't any variation on the level of clarity, but instead, each sentence was pronounced with 3 rates: *slow*, *normal*, *fast*.

In the third set, called the *isolated* set, the target words were pronounced, in isolation, first naturally, and then in response to the experimenter asking for clarity ("what ?").

2.2. Subjects and recordings

Simultaneous acoustic and articulatory recordings were collected in a sound booth, using EMA (Carstens AG100), for 2 native speakers of French, one female, one male. Five pellets were glued midsagittally to the apex, middle and dorsum of the tongue, and to the lower and upper incisors. The EMA data were sampled at 500Hz, the acoustic data at 16000Hz. In addition to the corpus, a calibration recording allowed us to trace the palate.

In order to correct the data for rotation in the midsagittal plane, the angle between the rear part of the palate traces and the horizontal axis was measured. All articulatory traces were rotated by this angle so that the new x-axis corresponds to the speaker's horizontal dimension and the y-axis to the vertical dimension. The articulatory data were then low-pass filtered, and normalized by the reference pellet to correct for head movements. Velocity and acceleration traces were obtained from the recorded position traces using a finite difference method.

3. RESULTS AND DISCUSSION

3.1. F0 contours

We first checked that the F0 contours followed the pattern described by Fougeron & Jun. As shown in figure 1, for the production of the AP /lilymine/ in the natural set, in initial position and in the normal condition, the /LHi LH*/ contour is observed, with the first L aligned with the first syllable [li], Hi roughly aligned with [ly], the second L with [mi] and H* with the last syllable [le]. Similar contours were observed for the other target words in initial position, with variations in the exact alignment of the Hi peak and in the height of the H* peak.

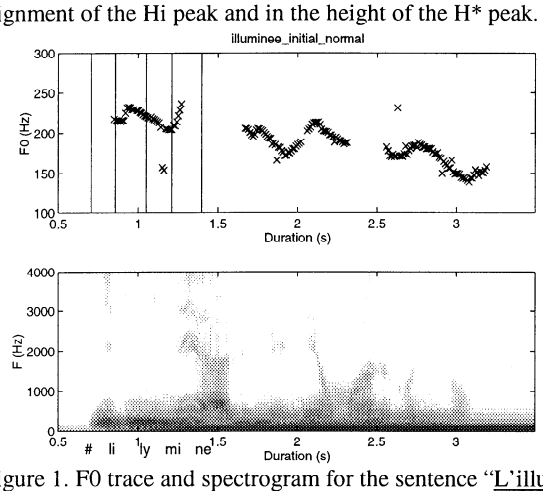

Figure 1. F0 trace and spectrogram for the sentence "L'illuminée a allumé néanmoins le monument.", normal condition.

3.2. Tongue movements

The second (clearer) productions of the target words in the isolated set were used to assess the tongue and jaw positions for /i/ and /a/. As expected, the articulation of /a/ corresponds to low tongue and jaw vertical positions and rear horizontal positions, whereas the articulation of /i/ corresponds to high vertical positions and front horizontal positions.

Among the 8 traces (horizontal and vertical positions of the tongue -apex, -middle and -dorsum and of the lower incisor), the vertical position of the tongue-middle showed the most variations. It was thus chosen as the representative articulator. As checked on the isolated set, the clearer /a/s feature lower tongue-middle vertical positions, the clearer /i/s higher positions.

For each of the studied syllables (/ma/, /la/, /li/, and /ni/), the tongue-middle vertical position at the time the vowel was fully reached, the peak velocity of the movement from the consonant to the vowel, and the duration of the syllable were measured, using hand-labeled events. The spectrogram of the acoustic signal, as well as velocity and acceleration traces, were used to mark these events. As shown in figure 2 for [la-no-ma-la], the beginning and end of the syllable were marked using the spectrogram (and listening to the signal) and gave the duration of the syllable. The tongue-middle minimum (respectively maximum) vertical position for /a/ (resp. /i/) was measured using zero-crossing of the velocity trace. The peak velocity was measured using zero-crossing of the acceleration trace.

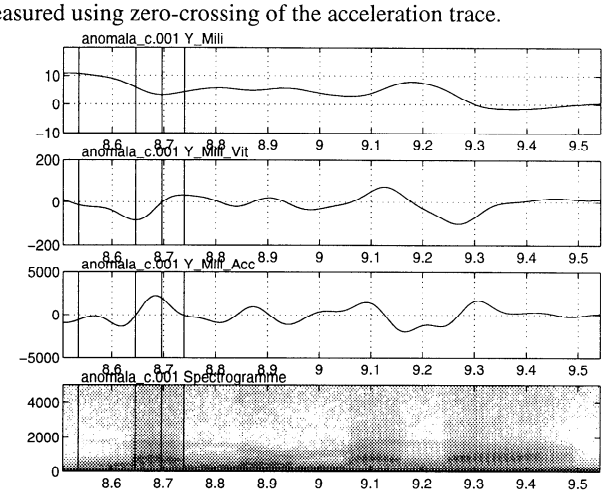

Figure 2. Articulatory labels for the first syllable of [lanomala] in 'Elle annihilait l'anomala en l'éloignant'. Top panel: tongue-middle vertical position (in mm), second panel: velocity (mm/s), third panel: acceleration (mm/s^2).

3.2.1. Natural set. Results of the articulation of the target words in the natural set are first analyzed. Figure 3 presents the comparison of the articulatory characteristics of /ma/ as the third (ma3) vs. fourth (ma4) syllable in the word. The syllable duration as a function of clarity is given in the top panel for the three positions in the sentence: initial (ma3i or ma4i), central (ma3c, ma4c) and final (ma3f, ma4f). The recordings of ma3f and ma4i are not available. In the normal condition, the differences in duration are not very marked. However, the mean duration for ma4 is longer than that for ma3. In the clear condition, the mean duration is higher in ma4 than ma3. In the clearest condition, the two groups are better separated, with ma4 always higher than ma3 whatever the position (but some data are missing). The subjects were not given any rate instruction in this set, they chose their own comfortable rate, given the clarity instruction. The differences in durations could therefore be due to differences in rate. However, the analyzed speaker was consistent in her adopted rates, and the separation between ma4 and ma3 could not be due to variations in rate.

The minimum tongue-middle vertical position for /ma/ is given in the middle panel of figure 3. In the normal condition,

ma4 tends to feature a lower tongue position (a higher displacement) than ma3. As the condition gets clearer, the separation between the tongue positions in ma4 and ma3 gets even more marked.

A similar pattern is displayed for the peak velocity in the bottom panel: it is higher in ma4 than ma3, and the difference between ma4 and ma3 gets larger as the condition gets clearer.

The increase in tongue displacement, duration and peak velocity can all be linked to the subject's effort to reach the appropriate tongue configuration and make the acoustic outcome more salient. We will refer to this conjunction of increases (see e.g. [8]) as hyper-articulation. The LH* tonal contour, aligned with the penultimate and final syllables, could correspond in the articulatory domain to a hypo-articulated (or normally-articulated) penultimate and a hyper-articulated final syllables.

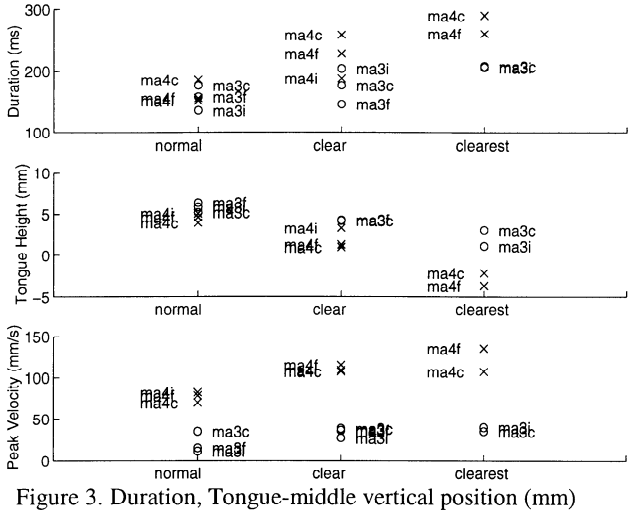

Figure 3. Duration, Tongue-middle vertical position (mm) and Peak Velocity for ma3 and ma4 (see text).

Figure 4 shows the measures for /li/ as the first (li1) vs. second (li2) syllable in the word. As concerns syllable duration, there is no clear separation of li1 and li2, even in the clearest condition: li1 is not generally longer than li2 (nor the reverse). As concerns tongue-middle vertical position, li1 tends to display more extreme (higher) positions than li2, but there are cases where li2 and li1 positions are similar. The peak velocities are rather weak, as the movement from /l/ to /i/ does not involve a large displacement. Although li2 seems to feature higher peak velocities, the differences are not large and there are exceptions.

The LHi tonal contour, whose alignment with the first two syllables is debated, seems to correspond to a more hyper-articulated first syllable and a relatively less articulated second syllable. But the difference is very subtle and some second syllables could even be more articulated than the first syllable. This irregularity could be a mirror of the loose tonal alignment.

The 'accent secondaire' is often described as tonally weaker than the 'primaire' (as in figure 1). However, there are speaking conditions (e.g. insistance) where the 'secondaire' becomes preponderant. The next analysis compares both accents in the articulatory domain. Figure 5 shows the measures for /la/ as the first (la1) vs. last (la4) syllable in the same word. The articulation of la1 is generally slower than la4 (there is a single exception). Both syllables belonging to the same word, duration differences could not be an artifact of rate. In the clearest condition, tongue-middle position is lower in la4 than la1. But in the other conditions, the positions for la1 and la4 are less distinguishable. There is no clear pattern for peak velocity.

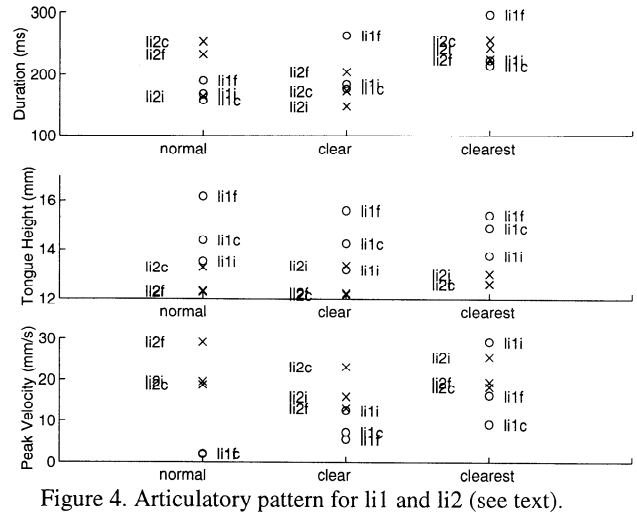

Figure 4. Articulatory pattern for li1 and li2 (see text).

Therefore, the last syllable is generally more articulated than the first but not markedly in the normal and clear conditions. It seems that the accent on the first syllable (which could correspond to an 'accent secondaire') is weaker but often comparable to that on the last ('accent primaire'). However, a further comparison between the second and the last syllables would be necessary to draw any conclusion on the relative articulatory strengths of the accents 'primaire' and 'secondaire', since the latter can be aligned with the second syllable.

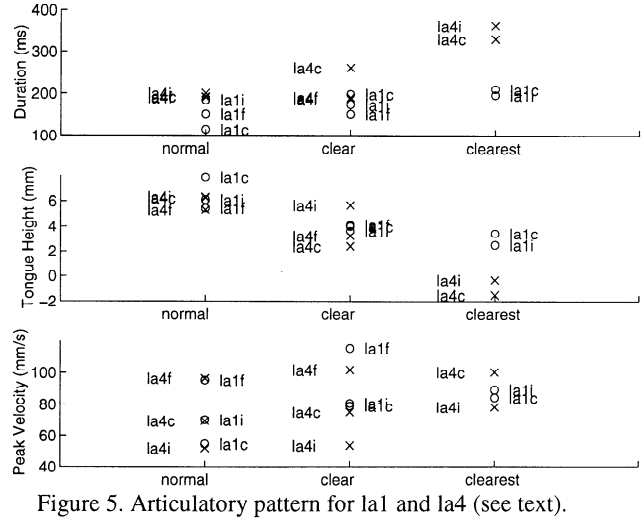

Figure 5. Articulatory pattern for la1 and la4 (see text).

3.2.2. Emphasis set. Contrastive emphasis is expected to make the observed articulatory pattern more salient (see [8], [9], [10]). Similar measurements were thus carried out for the emphasis set. Figure 6 shows the analysis of ma3 and ma4 under emphasis. The articulatory pattern conforms to our expectation: it resembles that in fig. 3, but with clearer differences between ma3 and ma4.

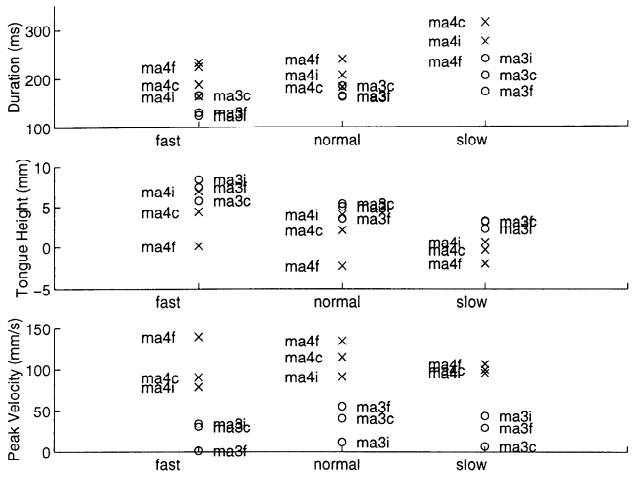

Figure 6. Pattern for ma3 and ma4 in the emphasis set (see text).

Results for li1 and li2 show the same trend (see figure 7): li1 is even better articulated than li2.

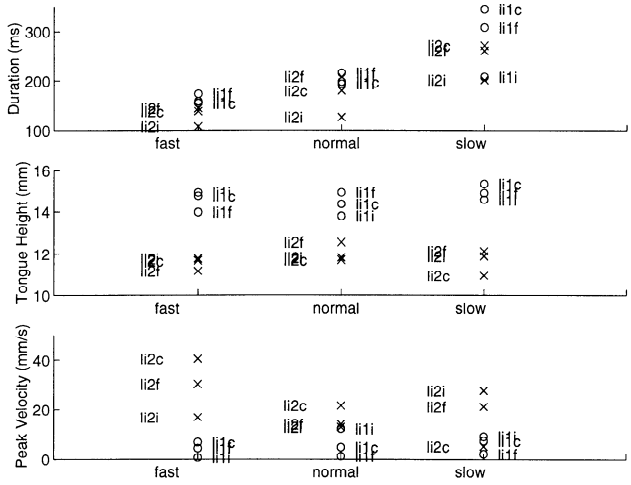

Figure 7. Pattern for li1 and li2 in the emphasis set (see text).

However the tendency for la4 to be more articulated than la1 is not made more salient by the presence of emphasis. Instead, as shown in figure 8, li1 is more often better articulated than li4. It seems therefore that the use of emphasis on the target word reinforced the accent on the first syllable which became as strong as, and sometimes stronger than, the accent on the last syllable. The so-called 'accent secondaire' can therefore, under emphasis, become the prime. This could be related to the 'accent d'insistance' described at the beginning of French words in some speaking styles (broadcasting or public speakers, see [11]).

4. CONCLUSION

This preliminary study suggests some articulatory correlates for the tonally-defined Accentual Phrase in French. The 'accent secondaire', or LHi, could be related to hyper-articulation (extension of the tongue displacement, increase in duration and peak velocity) of the first or second syllable of the AP, and the 'accent primaire', or LH*, to a hyper-articulation of the last syllable in the AP. The LH* contour has often been described as stronger than the LHi contour. Similarly, the hyper-articulation observed on the last syllable is stronger than that on the first syllable. However, when emphasis is present on the AP, the initial hyper-articulation can become as strong as, and even stronger than, the final one. An extension of the present corpus is considered to better describe the alignment of the articulatory correlates of LHi with the first two syllables in the AP.

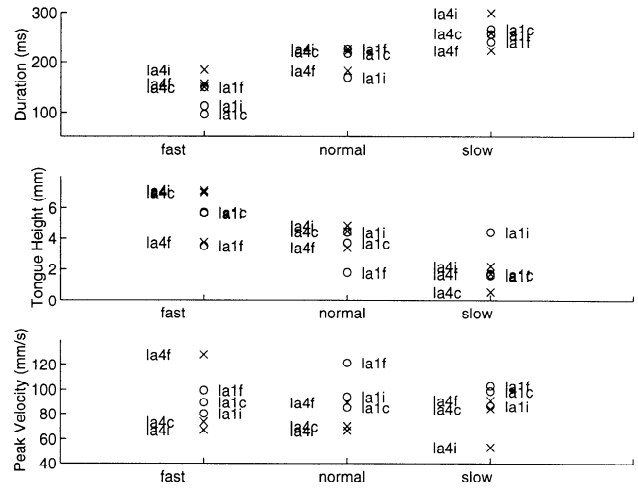

Figure 8. Pattern for la1 and la4 in the emphasis set (see text).

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REFERENCES

[1] Vatikiotis-Bateson E. & Kelso J.A.S. (1993). Rhythm type and articulatory dynamics in English, French and Japanese. *J. Phonetics*, **21**, 231-265.

[2] Jun S.-A. & Fougeron C. (1995). The accentual phrase and the prosodic structure of French. *Proceedings of XIIIth ICPhS*, **2**, 722-725.

[3] Fougeron C. & Jun S.-A. (1998).Rate effects on French Intonation: Prosodic organization and phonetic realization. *J.Phonetics*, **26**, 1, 45-69.

[4] Vaissière J. (1992). Rhythm, accentuation and final lengthening in French. In *Music, language, speech and brain*, J. Sundberg, L. Nord & R. Carlson, eds. Wenner-Gren, International Symposium Series, **59**, 108-120, Stockholm.

[5] Mertens P. (1993). Intonational grouping, boundaries and syntactic structure in French. *ESCA Workshop on Prosody*, Lund, **41**, 155-159.

[6] Rossi M. (1985). L'intonation et l'organisation de l'énoncé. *Phonetica*, **42**, 135-153.

[7] Pasdeloup V. (1990). *Modèle de règles rythmiques du français appliquées à la synthèse de la parole*. Thèse de Doctorat de l'Université de Provence, Aix-en-provence.

[8] de Jong K., Beckman M. E. & Fletcher J. (1991). The articulatory kinematics of final lengthening. *J. Acoust. Soc. Am.*, **89**, 369-382.

[9] Lœvenbruck H. (1996). *Pistes pour le contrôle d'un robot parlant capable de réduction vocalique*. Thèse de Doctorat Sciences Cognitives, INPG, Grenoble.

[10] Erickson D. (submitted). Effects of contrastive emphasis on jaw opening.

[11] Vaissière J. (1983). Language-independent prosodic features. In *Prosody: Models and measurements*, A. Cutler& R. Ladd (eds.), 53-66, Berlin, Springer.