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# ARTICULATION OF PROSODIC PHRASING IN FRENCH.

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## ABSTRACT

This study investigates how segmental articulation is affected by the position of a segment in a prosodic constituent in French. Linguopalatal contact, nasal flow or frequency of glottalization are compared for various segments placed in four different prosodic positions: Intonational Phrase-initial, Accentual Phrase-initial, Word-initial and Syllable-initial. Results show that segments initial in higher prosodic domains tend to have more linguopalatal contact, higher frequency of glottalization or lower nasal flow than segments initial in lower domains. Although the observed effects can vary in magnitude depending on the articulator, the speaker or the segment observed, these regular articulatory variations tend to reflect the prosodic encoding of utterances into constituents of various levels.

## 1. INTRODUCTION

While the segmental and suprasegmental aspects of speech have been most often studied separately, it becomes more and more obvious that these two aspects are closely connected. The study presented here aims to better understand this relationship by examining whether the segmental articulation of speech segments is affected by the prosodic organization of the sentence in which these segments are produced.

Most of the studies concerned with articulatory variations depending on prosodic factors have focused either on the difference between accented and unaccented segments or on the differences between initial and final position in a word or syllable [see 7 for a review]. Studies of the later kind are mainly concerned with finding some articulatory correlates of syllable- or word-boundaries and with the identification of a phonetic unit corresponding to the syllable or word. For example, compared to medial or final position, segments in initial position in these lower constituents have been found to have a higher degree of linguopalatal constriction [14, 2], a higher velum position [1, 11], or a larger glottal opening [4]. More recently, a few studies have shown that the articulation of initial segments also varies in higher level prosodic constituents [13, 9, 5, 6, 10]. Interestingly, these studies show that the articulation of initial segments varies depending on the prosodic level of the constituent. Hence, as shown for final lengthening [15], articulatory variations in initial position seem to reflect the hierarchical organization of prosodic constituents in distinguishing several levels of boundaries.

The work presented here summarizes some of the results of a comprehensive study of segmental articulatory variation determined by prosodic phrasing in French [7]. It extends the results found in other languages by examining different types of segments, articulators and prosodic constituents.

## 2. METHOD

Five consonants, varying in place and mode of articulation, /t, n, k, l, s/ and two vowels /i, ā/ have been studied. These segments have been placed in initial position of 4 different prosodic constituents: a syllable (S), a lexical word (W), an accentual phrase (AP), an intonational phrase (IP). Table I gives an example of the sentences used for the test segment /n/. In order to verify that the segment had been produced at the intended prosodic position, a transcription was done a posteriori with the following criteria: presence of a pause before the test segment (+ or Ø), lengthening of the preceding vowel (++, +, 0), demarcative function of the preceding tone (major boundary (%%), minor (%), not demarcative (Ø)). The coding used is illustrated in Table 1. All the test segments were produced with a low tone and were placed around the 5th syllable of the sentences.

	pause	lengthening V1	boundary tone
1- IPi :	+	++	%%
La pauvre <b>Tata</b> . <b>Nadia</b> et Paul n'arriveront que demain. (Poor Aunti, Nadia and Paul will arrive only tomorrow.)			
2- APi :	Ø	+	%
Tonton, <b>Tata</b> , <b>Nadia</b> et Paul arriveront demain ... (Uncle, Aunti, Nadia and Paul will arrive tomorrow...)			
3- Wi :	Ø	0	Ø
Tonton Paul et <b>Tata</b> <b>Nadia</b> arriveront demain par le train. (Uncle Paul and Aunti Nadia will arrive tomorrow...)			
4- Si :	Ø	0	Ø
Tonton Paul et <b>Tata</b> <b>Annabelle</b> arriveront demain ... (Uncle Paul and Aunti Annabelle will arrive tomorrow...)			

Table I: Criteria used for the prosodic coding. Example of sentences in which the test segment /n/ (in bold) is placed in initial position in an Intonational Phrase (IPi), an Accentual Phrase (APi), a Word (Wi) and a Syllable (Si).

Articulatory variations depending on prosodic position are assessed in terms of (1) linguopalatal contact (as measure with electropalatography, Kay Palatometer) for all the consonants and /i/, (2) amount of nasal airflow (measured with a Rothenberg mask) for the nasals (/n/ & /ā/), and (3) frequency of glottalization for /i/.

Except for the nasal flow analysis, for which 4 Parisian French speakers have been studied, the remaining analyses include two speakers (A and B, the author). For these speakers a pseudo-palate covered with 96 electrodes has been made with a special layout extending the electrode coverage to the front of the mouth in order to capture dental articulation.

In general, 20 repetitions of each prosodic position have been recorded except for /l/ (10 rep.) and /k, i/ (15 rep.). Comparison between prosodic position was tested with an

ANOVA and post-hoc Fisher PLSD tests (with a 95% level). In the following presentation, a prosodic position is considered significantly different if it is different from *all* the other positions.

### 3. RESULTS

#### 3.1 Lingual articulation of consonants

Variation in the lingual articulation of consonants depending on their prosodic position was measured in terms of amount of linguopalatal contact (% of electrode contacted) and distribution of the contact over the palate. These measurements have been taken at the point where the contact is maximal during the consonantal constriction.

Results show that the amount of linguopalatal of the three stops /t, n, k/ vary depending on the position of the consonant. The amount of linguopalatal contact of initial segments tends to increase progressively from the lowest constituent (Si) to the highest constituent (IPi). Figure 1 illustrate this variation for speaker A.

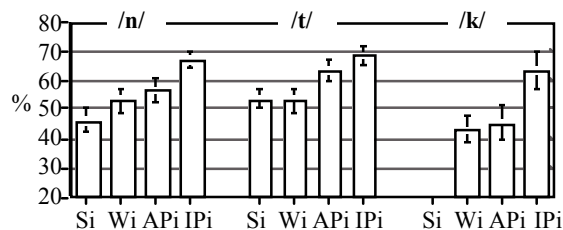


Figure 1: Amount of linguopalatal contact for the stops /n/, /t/, et /k/ in the different prosodic positions examined. Results for speaker A.

For /n/, this increase of linguopalatal contact allow to distinguish significantly the 4 positions considered for the 2 speakers (Si<Wi<APi<IPi). For /t/, only 3 positions are distinguished by the progressive increase of linguopalatal contact. Speaker A does not show a distinction between Syllable and Word levels (Si/Wi<APi<IPi) and for speaker B, the Word level is not distinct from either S or AP (Si<APi<IPi). For /k/, only Wi, APi and IPi positions are examined. For speaker B, all these 3 positions are distinguished by the amount of linguopalatal contact, while for speaker A there is only a two ways distinction between Wi/APi and IPi. The difference between Wi and APi follows the same trend with a greater amount of contact in APi but the difference is marginally significant (p=.05).

For the 3 stops, the increase of linguopalatal contact in initial position of higher level constituents is reflected by a widening of the surface of occlusion, toward the back of the palate for the front stops /t, n/ and toward the front part of the palate for the back stop /k/.

Articulation of the lateral /l/ shows a similar variation depending on prosodic position. A central region and 2 lateral regions have been defined on the palate and are illustrated on Figure 2. For the 2 speakers, the amount of linguopalatal contact differentiate a sub-lexical level (Si), a lexical level (Wi) and a supra-lexical level (APi/IPi). This distinction follow the trend observed for the other stops: an increase of contact in higher constituents. By examining lateral contact, one can observed for

the 2 speakers an increase of contact on the side of the lateral opening (right/white for speaker A in figure 2) accompanied by a decrease of contact on the side where the tongue is anchored (left/black for speaker A). As a result, /l/s has a smaller asymmetry of tongue contact in initial position of higher constituents along with a widening of the central contact.

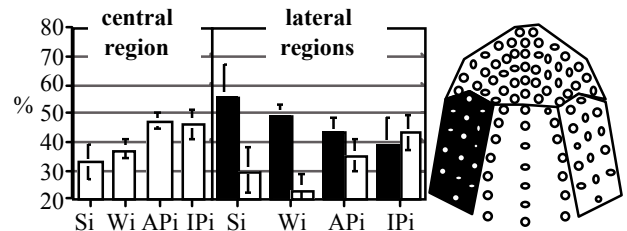


Figure 2: Amount of linguopalatal contact for /l/ in the central region (gray) and lateral regions (right: white, left: black). Results for speaker A.

The articulation of the fricative /s/ is comparatively less affected by prosodic position. Observations are restricted to the anterior region where the fricative groove is located (figure 3). For the 2 speakers, some variations can be observed but the tendency is less clear than that of other consonants. Excluding the Si position, there is an increase of contact from Wi to APi/IPi for speaker A, and from Wi/APi to IPi for speaker B. Contact in Si position is quite large and varies depending on the speaker. The small effect of prosodic position on /s/ could be explained by the fact that this consonant is less subject to articulatory variation in general.

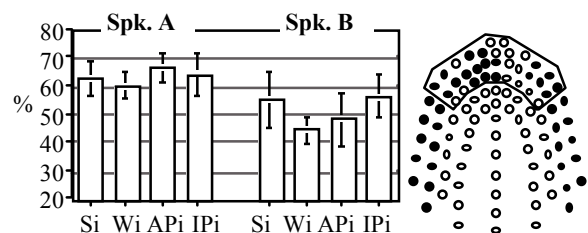


Figure 3: Amount of linguopalatal contact for /s/ in the anterior region depending on prosodic position.

#### 3.2. Velic articulation of nasals

The amount of nasal flow depending on prosodic position has been observed for the nasal consonant /n/ and the nasal vowel /ã/. Measurements have been made at the point of maximal flow in the segment. Nasal flow is considered here as an indirect measurement of velum height although the relation between the two is not so direct.

For both nasal segments, there seem to be a tendency for nasal flow to decrease from initial position in lower constituent to initial position in higher constituent. However, the variation is less striking than that of lingual articulation. Results vary depending on the speakers, the contexts (/ana/ and /ini/ sequences are studied) and the segments (/n/, /ã/). For /n/, there is a common pattern for 3 of the 4 speakers: a significant diminution of nasal flow in IP initial position compare to lower constituents. Some speakers show some distinction between intermediate

constituents but not always in the two vowel contexts. For /ã/, there is a diminution of nasal flow for 2 of the 4 speakers and no variation for the others. For these 2 speakers, one shows a gradual diminution between 3 positions (Wi>APi>IPi), while the other presents only a two-way distinction (Wi>APi/IPi). Therefore, only the diminution from Wi to IPi is common to these speakers.

### 3.3. Lingual and glottal articulation of /i/

The amount of linguopalatal contact during the articulation of the closed vowel /i/ has been measured at the point of maximal contact. Only 3 positions are compared: Wi, APi, IPi.

As shown for the consonants, the lingual articulation of the vowel varies depending on prosodic position. The trend of the variation is similar to that of the consonants, but a smaller number of positions are distinguished this way. For the 2 speakers there is an increase of contact in supra-lexical levels (APi/IPi) compare to the lexical level (Wi) (see figure 4).

Along with this variation differentiating the word level from higher levels, there is a distinction in glottal articulation. The frequency of glottalization at the onset or during the vowel has been determined acoustically. Results show that, in this data, /i/ is never glottalized in Word-initial position while it is frequently glottalized in initial position of higher phrasal constituents. Depending on the speakers, the frequency of glottalization in the higher constituents is progressive (speaker B) or specific to a position (APi for speaker A).

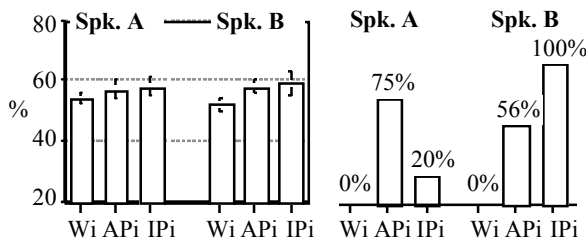


Figure 4: On the left, amount of linguopalatal contact for /i/ (spk A&B) and on the right, frequency of glottalization of the vowel depending on prosodic position.

## 4. DISCUSSION AND CONCLUSION

As it has been observed in the literature for word and syllable, segments initial in higher level constituents have particular articulatory characteristics. The articulatory variations observed allow distinctions within initial position in several prosodic constituents as well as distinctions within position in one constituent, since an initial segment in a lower constituent (e.g. a word) is also medial in a higher constituent (e.g. an AP).

The articulatory variations observed follow a general tendency: what ever the nature of the variation, its magnitude tends to increase from initial position in a lower constituent to initial position in a higher constituent. As a consequence, these variations reflect the hierarchical organization of prosodic constituents (i.e. of boundaries strength). However, as shown in the results presented here, there is a large amount of variation in the observed trend depending on segments, articulators, speakers

and constituents. This is illustrated in table II for linguopalatal contact.

Prosodic position affects clearly the articulation of the stops and the lateral observed, and to a smaller extent the vowels. On the contrary, the lingual articulation of fricative seems to be less affected by prosodic position. As said earlier, this finding is not surprising and may reflect the smaller overall variability of this consonant. The results for nasal flow are also less clear than that of linguopalatal contact. It is difficult, however, to know whether this reflects a smaller variability of the velic articulation (nasal flow being an indirect measure of velum height) or whether this is due to the technique used (aerodynamic data being known to be quite variable).

Another factor of variability is the speaker. In the nasal flow data, this is reflected in the behavior of one speaker for /n/ and two speakers for /ã/ who do not follow the tendency of the others. For linguopalatal contact, it can be seen in table II that, although the two speakers make several distinction between the prosodic positions, there is only 3 cases where the speakers share exactly the same distinctions (for /n/, /l/, and /i/).

Contact	Spk. A	Spk. B
/n/	Si< *Wi< *APi< *IPi	Si< *Wi< *APi< *IPi
/t/	Si-Wi< *APi< *IPi	Si< *APi< *IPi
/k/	Wi-APi< *IPi	Wi< *APi< *IPi
/l/	Si< *Wi< *APi-IPi	Si< *Wi< *APi-IPi
asymmetry	Si-Wi> *APi> *IPi	Si-Wi> *APi-IPi
/s/	Wi< *APi-IPi	Wi-APi< *IPi-Si
/i/	Wi< *APi-IPi	Wi< *APi-IPi

Table II: summary of the results observed in the EPG experiment depending on segments and speakers. <\* means "significantly greater than".

The testing of several prosodic levels in this study has shown that, while regular distinctions are made between initial positions in several constituents, all the constituents are not always distinguished this way. For linguopalatal contact for example, the variations observed in initial position allow to differentiate at least 2 levels of constituents for /s/ and /i/ and at the most 4 (out of 4) constituents for /n/. The most robust distinction is made between the most extreme constituents in the hierarchy (IP and Si-Wi).

The word level does not appear to be clearly different from either Si or APi in our data. This fact has to be interpreted with caution, since the definition of "word" in our corpus is lexical. It is possible that what I considered as a Wi position in a sequence like "Tata Nadia" does not correspond to an initial position in a prosodic word (whose definition remains to be defined for French).

The variability found in the amount and nature of the constituents differentiated by articulatory variation is congruent with the results observed in other studies (see [10] for English, Korean and Taiwanese). It is also the case that variations depending on position in word or syllable like positional allophones are not always realized by speakers. This fact suggests that prosodically-induced articulatory variations are optional. This leads to the question of whether these variations are intentionally produced by the speakers or whether they are

side effects of other prosodic variation. A comparison with segmental duration has shown that variations observed in the articulatory parameters studied are only weakly correlated to lengthening of the segments (but see Keating et al. 98 for a different result for Korean). In addition, the effect can not be reduced to variations in pausing or intonation contour in this study (see Fougeron 98 for more details).

Another puzzling question relates to the physiological nature of the mechanism involved in these articulatory modifications. The variations observed for lingual articulation in French follow the same trend than those observed in English [6, 3], Korean and Taiwanese [10]: an increased lingual constriction in higher constituents. The reduction of nasal flow is similar to that observed in Estonian [8] and comparable to the raising of the velum in word-initial position in English [11, 16]. The increased frequency of glottalization at the beginning of higher constituent was also observed in English [13, 5]. Most of these articulatory variations are similar to the characteristics commonly described for "strong" or "fortis" segments [e.g. in French 12] and "strengthened articulation" [15]. While the term remains to be accurately defined from an articulatory point of view, phrasal articulatory variations observed in initial position may be interpreted as "articulatory strengthening".

The signaling of prosodic boundary is undoubtedly multi-parametric. Acoustic cues provided by final lengthening and melodic contours may be the most robust and the most important for the perception of phrasing. However, this study in French confirms the fact that the prosodic phrasing of an utterance is also reflected in the articulation of initial segments. The relevance of this finding on perception and its linguistic function remain to be explored.

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