Looking for acoustic cues of resyllabification in French

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ABSTRACT

In this paper, we address the question of whether so-called "resyllabification" is total in French. Durational properties of vowels and consonants in a sequence with "enchaînement" (V1.C#V2) are compared with phonetically similar sequences containing a word-initial consonant (V1#CV2), and a non-word-initial syllable-onset consonant (V1.CV2). This three-way comparison shows that although inter-speaker and inter-consonant type differences exist, the enchaînement consonants generally differ from underlying syllable onsets (word-initial or not) by showing a shorter duration. Moreover, lexical and syllabic boundaries may be differentiated by cues on the pre-consonantal vowel rather than on the initial consonant. These results provide further evidence that resyllabification can be partial in French, and that the surface form of so-called "resyllabified" sequences can preserve cues of their abstract lexical and syllabic structure.

1. INTRODUCTION

A long term debate in phonetic research has been to determine whether some acoustic and/or articulatory cues can signal word boundaries. Several studies have isolated subtle phonetic characteristics that reflect the presence of word boundaries (e.g. initial/final lengthening, positional allophones, vowel glottalization, consonant final lenition, see [1] for a review). However, these cues are not systematically present and vary not only with the speaker but also with the language studied and with the segments considered. Furthermore, it is not clear whether these properties are cues to word boundaries or to syllable boundaries. First, most of the differences between initial vs. final consonants cited in the literature come from examination of monosyllabic words, i.e. cases where word and syllable boundaries overlap. Second, the few comparisons reported in the literature between syllabic and word boundaries show little evidence for a phonetic distinction. For example, Krakow [2] has shown that the articulation of the segment /m/ is different between initial and final consonants (e.g. *home E* vs. *Hoe me*) but not between word initial and syllabic onsets consonants (e.g. *Hoe me* vs. *Homey*). Moreover, when compared to other boundary types, lexical boundaries are less distinct from syllable boundaries than from higher constituents boundaries. For example, in French, the observation of nasal and lingual articulation for consonants placed in different prosodic positions has shown that word initial consonants are more similar to syllabic onsets than to Intonational Phrase initial or Accentual Phrase initial consonants (Fougeron [3]).

Nonetheless, word initial phonetic properties have been shown to be used by listeners in segmenting ambiguous sequences (e.g. Rietvelt [4], Quené [5]). Therefore, the question of whether some phonetic cues could reflect word boundaries remains crucial, not only to understand how listeners perceive and segment the speech flow, but also in order to specify speech encoding units (cf. discussion).

This paper addresses more specifically the central question of the word as a phonetic unit by examining cases of non-alignment between word- and syllable-boundaries. In French, the "enchaînement" of a word-final consonant to the following word-initial vowel (or consonant) across word boundaries is usually considered as a total resyllabification of the speech chain. Indeed, resyllabified consonants have been described as phonetically similar to word or syllable initial consonants (Passy [6]; Grammont [7]). Hence, a sequence like *jeune ami* 'young friend' is usually considered to be syllabified as [ʒœ.na.mi]. However, several studies have suggested that resyllabification is only partial in French, by showing that resyllabified consonants can be acoustically distinguished from underlying word-initial consonants ([8], [9], [10], [13], [16]; [11] and [12] in the case of schwa deletion). For example, Dumay et al. ([13]) showed that strings with an enchaînement of two consonants across a word boundary (e.g. *tante roublarde* 'crafty aunt'), differ from strings including an underlying word-initial cluster (e.g. *temps troublants* 'disturbing weather'). The authors compared 48 pairs of the type (a)V1C1#C2V2 vs. (b)V1#C1C2V2 produced by 8 French speakers, and found condition (a) to be distinguished by a longer duration for both V1 and C2. These durational differences were systematic for stop+liquid sequences but absent for fricative+plosive ones. More interestingly, the authors showed that listeners can use these cues in on-line segmentation processes.

The present paper follows up on Dumay's work by looking at cases of enchaînement between a single consonant and a vowel (V1#CV2) and by adding a third comparison in the experimental design. Indeed, a three-way comparison is

done between sequences containing a so-called resyllabified consonant, a sequence containing a word-initial consonant, and a sequence containing a non-word-initial syllable onset. The main goals of this study are: (1) To investigate whether acoustic variations can distinguish word initial consonants from syllabic onsets. (2) To determine whether resyllabified consonants share temporal properties with syllabic onsets. A positive answer to this question would provide evidence in favor of a phonetically realized resyllabification in French. (3) To determine whether, despite a possible syllabic reorganization of the sequence, lexical boundary cues are still present in resyllabified sequences. A positive answer to this question would support the hypothesis that resyllabification is partial in French, and that the underlying structural organization of a sequence is maintained in production even in the case of surface resyllabification [12, 13].

2. METHOD

Experimental conditions: A corpus of 35 triplets including a sequence V1CV2 was constructed. As shown in table I, these triplets had identical segmental content, but differed according to the location and the type of boundary involved in the string (syllable- or word-boundary). Condition A was created in order to involve an enchaînement between the two words of the pair (V1.C#V2, e.g. *cale égale* 'equal wedge'). According to a traditional description of resyllabification, the surface structure of this sequence has a syllabic boundary (.) between V1 and C, and a lexical boundary (#) between C and V2. Thus, while C is underlyingly a word-final consonant and therefore at some level assumed to be in syllable coda position, it is said to surface as the onset of the CV2 syllable.

Table 1: Boundary conditions studied.

	Conditions		Examples
A	enchaînement	$V_1.C\#V_2$	« cale égale »
B	word boundary	$V_1\#CV_2$	« cas légal »
C	syllable boundary	$V_1.CV_2$	« qualégale »

As in condition A, the sequence investigated in condition B straddles a word boundary. However, in this case the lexical boundary occurs after the first vowel (V1) of the sequence (V1#CV2, e.g. *cas légal* 'legal case'). In both surface and abstract form, C is word initial (and syllable onset). Finally, in condition C, the sequence does not straddle a word boundary, and a syllabic boundary occurs between V1 and C (V1.CV2, e.g. non-word *qualégale*). C is thus a syllabic onset.

Corpus construction: Two lists of lexical items have been extracted from the Brulex database (Content et al. [14]) by selecting words ending (list 1) or beginning (list 2) with a same consonant. One of the major constraints was to choose items able to be transformed into other French words when the consonant was removed (e.g. list 2: *légale* 'legal' > *égale* 'equal'; list 1: *cale* 'wedge' > *cas* 'case'). Then, 35 pairs of words were constructed from these two different lists in order to obtain (Noun+Adj.) or (Adj.+Noun) sequences (e.g. *un cas légal* vs. *une cale égale*, *un mec allemand* 'a German guy' vs. *un met calmant* 'a calming dish'). For the third condition, it was unfortunately not possible to find enough French word with the required structure. Therefore, 35 non-words including the same VCV sequence were created. Finally, each member of the triplet was included in a syntactically and semantically plausible carrier sentence controlled for length, sequence position in sentence, and expected prosodic structure. More particularly, caution was taken to place the two word sequences in a single accentual phrase to avoid a final accent on the first word.

Material and measurements: These sentences were read in a random order by 8 Swiss French naive speakers. The 35 triplets included 3 consonant types: stops (22 triplets with either [p, b, t, d, k, n]), fricatives (9 triplets with either [f, s, ʃ]), and liquids (4 triplets with [l]). The vowels /i, y, ɛ, a, ã, ɔ̃/ and /i, y, e, ø, ɛ, ɛ̃, a, ã, o, ɔ̃/ appeared in V1 and V2 position respectively. These (V1CV2) sequences were segmented and the duration of the segments was measured with Praat. Data from the 8 speakers were spilt between 3 phoneticians who did the segmentation independently (for 2 or 3 speakers each). Cross-labelling comparison was done between the 3 phoneticians on the recordings of one speaker to ensure the validity of the measurements. High positive correlation was found between the labellers (between 0.8 and 0.9).

3. RESULTS

Durational properties of V1, C and V2 depending on the 3 boundary conditions were compared with repeated measures ANOVAs and two-ways planned comparisons between the conditions. The effect of the boundary condition was first examined over all speakers, then by speaker and by consonant type.

V1 duration: Over all speakers, the durational characteristics of V1 depend on the boundary condition $(F(2,544)=37.72; p<.0001)$. The pre-consonantal vowel is significantly longer in condition A and B than in condition C; that is, when the vowel is the nucleus of the word-final syllable (A: V1C#), or when it is a word-final vowel (B:V1#) compared to when it is word-internal (C: V1.CV2). However, a significant interaction between the effect of the boundary condition and the speakers $(F(14,544)=3.79; p<.0001)$ shows that this duration variation of V1 depends on the speaker. Subsequent ANOVAs by speaker show that this main effect of the boundary condition is significant for 5 of the 8 speakers (s2,3,5,6,7). As illustrated in Figure 1a, these speakers have a longer vowel in conditions A and B compared to C. This two-way distinction (A-B vs. C) is significant for 3 of the speakers (s2,3,5), while s6 shows a

significant difference only between conditions A and C, and s7 between conditions B and C (difference between conditions A and C is marginally significant). Therefore, the enchaînement condition (A) and the pre-word boundary condition (B) are not significantly distinct for 7 of the speakers (s8 showing a difference A>B). On the other hand, the word-final vowel (B) is significantly longer than the word-internal vowel (C) for half of the speakers (s2,s3,s5,s7).

Furthermore, as illustrated in Figure 2, the main effect of boundary condition over all speakers is found for the three types of consonant (fricatives: $F_{(2,142)}=15.00$; $p<.0001$; stops: $F_{(2,159)}=13.45$; $p<.0001$; liquids: $F_{(2,62)}=9.35$; $p<.0003$), with the same trend (longer V1 in condition A and B vs. C).
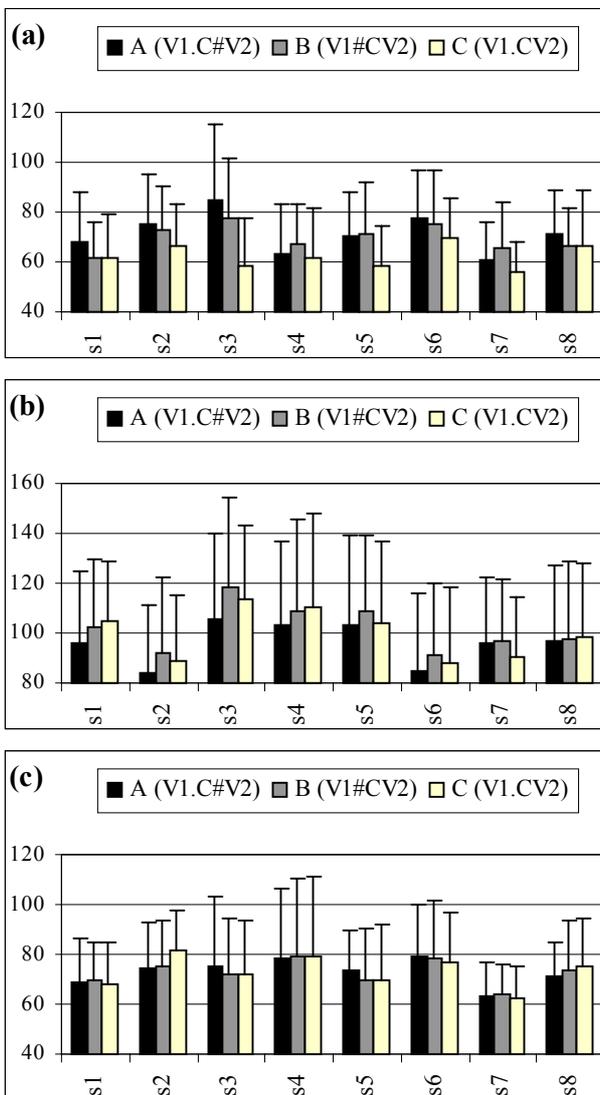

Figure 1a,b,c: Duration of V1(a), C (b), & V2 (c) depending on boundary conditions (A, B, C) and speakers.

C duration: The duration of the consonant also varies according to the boundary condition. This effect is significant over all speakers ($F_{(2,544)}=19.89$; $p<.0001$), the so-called resyllabified consonants (cond. A) being

significantly shorter than both word-initials (cond. B) and syllable-onset (cond. C) consonants. On the other hand, word-initial consonant (cond. B) is significantly longer than syllable-onset consonant (cond. C). As illustrated in Figure 1b, although a significant interaction holds between boundary conditions and the speakers ($F_{(14,544)}=2.06$; $p<.01$), a shorter resyllabified consonant (A) is found for all speakers, except s7 and s8 (with a marginally significant main effect for speaker s5). The consonant in condition A is significantly shorter than both conditions B and C for 3 speakers (s1,s2,s4), and it is significantly shorter than B for the 3 others (s3, s5, s6). On the other hand, the distinction between word-initial (B) and syllable-onset (C) consonant is significant for only one of the speaker (s5).

A comparison between the different consonant types shows that the influence of the boundary condition on consonant duration is mainly due to the stops' behavior (see Figure 2). Indeed, only stop consonants show a significant main effect ($F_{(2,350)}=27,80$; $p<,0001$), with resyllabified stops being shorter than both underlying onset consonants (cond. B and C). For the other types, the only significant difference is found between fricatives in condition B and C.
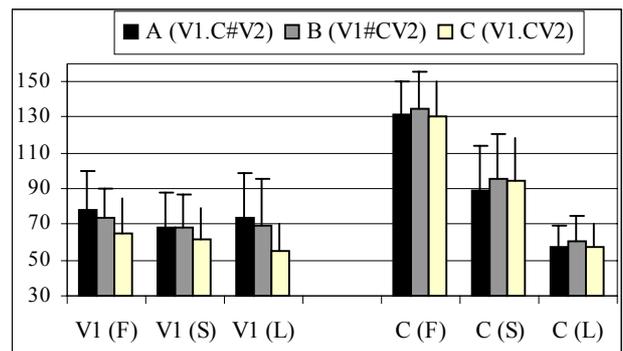

Figure 2: Duration of V1(left) and C (right) depending on boundary conditions (A, B, C) and consonant type (F: fricatives, S: stops, L: liquids) (std deviations in error bars)

V2 duration: Over all speakers comparison of V2 duration, does not show any effect of the boundary condition. This absence of effect holds for all speakers except s2 who shows a significantly longer V2 in condition C compared to the two other conditions.

However, analysis by consonant types show unexpected significant effects: in the resyllabified condition (A), V2 is significantly shorter after stops, but longer after liquids compared to conditions B and C. No effect is found with fricatives.

4. DISCUSSION AND CONCLUSIONS

This study confirms previous results in the literature concerning the subtle acoustic differences between word and syllable boundaries. Indeed, in terms of durational properties, only few differences are found between condition B and C, and when present, these are found on the pre-consonantal vowel (V1) rather than on the initial

consonant itself. Thus, while word-final lengthening of V1 is attested for half of the speakers, consonant word-initial lengthening is only found for one speaker.

Regarding the durational properties of the enchaînement sequences, our results provide further evidence that so-called resyllabification is not always complete in French. Indeed, compared to the syllable-boundary condition, the enchaînement condition was found to be distinguished by both (1) a longer V1 for half of the speakers (the trend being shared by 7 speakers) and (2) a shorter consonant for 3 of the speakers (the trend being shared by 5 speakers). Moreover, when compared to the word-boundary condition, the enchaînement sequence is distinguished by a shorter consonant for 6 of the speakers. Therefore, it appears that the enchaînement consonant adopts the durational properties of neither syllabic onsets, nor word-initial consonants. It rather seems to maintain the durational properties of reduced/shorten coda consonants (although this has to be confirmed by a comparison with a control condition including a word final consonant without enchaînement). Hence, these results contradict the view that enchaînement in French implies a simple re-syllabification of the word-final coda consonant to the onset of the following syllable.

However, a fuller understanding of the enchaînement process needs to account for the variability observed, both in our data, and in the results reported in the literature. Indeed, the durational properties found to distinguish sequences with enchaînement were not produced by all the speakers, nor were they present for all the consonant types studied. A more comprehensive study of the acoustic and articulatory properties of these sequences needs therefore to be done. Furthermore, even though our conclusions are in line with those of Dumay et al. [13], the two studies show contradictory results regarding the durational properties that differentiate enchaînement sequences. Indeed, they found a difference in V1 duration while we do not, and no difference in the duration of the enchaînement consonant while we do. (Recall that Dumay et al. only compared our conditions A and B, and looked at enchaînement between 2 consonants.)

Nonetheless, the fact that resyllabification is not always phonetically realized in enchaînement sequences raises interesting questions on the role of the syllable in both perception and production processes. Indeed, when available, the use of these phonetic cues by listeners ([13], [16]) provides counter-arguments to opponents of syllable-based segmentation strategies: if phonetically cued, enchaînement would not imply a misalignment between word and syllable boundaries ([13]). Moreover, the preservation of phonetic cues of the underlying lexical structure and abstract syllabification of the words involved in so-called resyllabified sequences challenges models of speech production assuming a resyllabification at the level of phonological syllables (e.g. Levelt et al. [15]). These results also further support the view that non contrastive phonetic details characterizing position in words have to be part of the lexical representations (eg. [12]).

REFERENCES

[1] Fougeron C*., Variations articulatoires en début de constituants prosodiques de différents niveaux en français.* Thèse de doctorat, Paris 3, 1998.

[2] Krakow, R. A., *The Articulatory Organization of Syllables: A Kinematic Analysis of Labial and Velic Gestures*. PhD diss., Yale Univ., 1989.

[3] Fougeron C., Articulatory properties of initial segments in several prosodic constituents in French. *Journal of Phonetics,* 29(2), pp. 109-135, 2001.

[4] Rietveld A., Word boundaries in the French language. *Language and Speech*, 23(3), pp.289-296, 1980.

[5] Quené, H., Durational cues for word segmentation in Dutch. *J. of Phonetics*, 20, pp. 331-350, 1992).

[6] Passy, P., *Les sons du français.* Paris : Didier, 1917

[7] Grammont M., *Traité de phonétique*, Paris: Delagrave, 1933.

[8] Rousselot, P.J., *Principes de phonétique expérimentale*. Paris: Welter, 1901

[9] Durand, M., *Le genre grammatical en français parlé à Paris et en région parisienne*, Paris: Bibliothèque du Français Moderne, 1936.

[10] Besson, C. & Grosjean, F., L'effet de l'enchaînement sur la reconnaissance des mots dans la parole continue. *L'année Psychologique,* 96, 9-30, 1996.

[11] Rialland, A. Schwa et syllabes en français, in *Studies in compensatory lengthening,* E. Sezer & L. Wetzels Eds., pp. 187-226. Dordrecht: Forris, 1986.

[12] Fougeron, C. & Steriade, D., Does deletion of French schwa lead to neutralization of lexical distinctions? *Proceedings of Eurospeech97*, pp. 943-946, 1997

[13] Dumay, N., Content, A. & Frauenfelder, U.H. Acoustic-phonetic cues to word boundary location: Evidence from word spotting. *Proceedings of the 14th ICPhS*, San Francisco, pp. 281-284, 1999.

[14] Content A., Mousty P., Radeau M. "Brulex : une base de données lexicales informatisée pour le français écrit et parlé " *L'Année Psycholgique*, 90, pp.551-566, 1990.

[15] Levelt, W.J.M., Roelofs, A., & Meyer, A. S., A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22*, pp.1-75, 1999.

[16] Gaskell, G., Spinelli, E. & Meunier, F. Perception of resyllabification in French. *Memory and cognition, 30(5),* pp.798-810, 2002.