Temporal coordination of CV: The case of liaison and enchaînement in French

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OVERVIEW: Syllable structure is hypothesized to be associated with a characteristic pattern of temporal coordination [1-4]. The coupled oscillator model hypothesizes that CV is coordinated in-phase while VC is coordinated anti-phase with each other. However, a consonant which was an underlyingly coda consonant can also be resyllabified to the following syllable when it is followed by a vowel. Fundamental questions are whether a resyllabified consonant is a 'true' onset, and whether it is shown in the coordination pattern. In French, there are two different types of resyllabification: 1) the resyllabification of an underlying word-final coda (Enchaînement CV); 2) the resyllabification of a word final liaison consonant, i.e., a latent consonant surfacing only when the following word starts with a vowel (Liaison CV). As shown in Table 1, for example, these two resyllabification cases and the case with a true word-initial onset consonant (Onset CV) are distinct underlyingly, but are said to be homophonous in French. However, acoustic studies have shown that the phonetic neutralization between forms like the ones presented in Table 1 is incomplete: liaison and enchaînement consonants can be shorter in acoustic duration, the vowel preceding them can be longer, and/or they can preserve some specific allophonic properties associated with their word-final position [e.g., 5-10]. Furthermore, an articulatory study from two Quebec French speakers also showed that Liaison is articulatorily different from Onset and Enchaînement, (e.g., a smaller magnitude release gesture) with mixed results for different kinds of lexical items [11].

THE TEMPORAL COORDINATION: Shaw et al. [12] hypothesized that for complex segments, such as /pʲ/, the onset of G2 is temporally coordinated with the onset of G1, while for segment sequences, such as /pj/, the onset of G2 is temporally coordinated with the offset of G1. These competing coordination relations were explored by investigating how the lag between the onset-to-onset varied with G1 duration. They found that for complex segments (palatalized consonants in Russian, such as /pʲ/), variation in duration had little effect on lag. In contrast, for English segment sequences (such as /pj/), as consonant duration increased, so too did the lag between consonant and glide gestures, showing a strong positive correlation. Exploiting this temporal diagnosis, the current study aims to understand the temporal coordination of three different CV types (Onset CV, Enchaînement CV, and Liaison CV). The present study asks the following research questions: 1) Is there a temporal difference among the three different types of CVs and does this difference hold at different speech rates? 2) Do the different types of CVs affect the temporal coordination of gestures in terms of the relationship between C duration and lag?

EXPERIMENT: Three female native speakers of French participated. The materials include the three minimal and near-minimal triplets, where each triplet consisted of an Onset CV, Enchaînement CV, and Liaison CV. The target sequences were produced within a carrier sentence, and each sentence was produced 14 times (7 at normal and 7 at fast speech rates). Sensors, attached to the upper and lower lips, jaw, tongue tip (TT), tongue blade (TB), tongue dorsum (TD), and left/right mastoids were tracked by means of Electromagnetic Articulography (EMA, AG501) and an audio-recording setup. The TT sensor indexed the consonant gesture /t/ and the TD sensor was used to identify the vowel gesture /a/. Articulatory movements were parsed using a custom Python script, which identifies temporal landmarks of gestures with reference to the velocity signal. The four key temporal intervals computed from these articulatory landmarks were (1) consonant duration: $C_{DURATION} = C_{RELEASE} - C_{TARGET}$; (2) gestural overlap: $OVERLAP = C_{RELEASE} - V_{ONSET}$; (3) lag between the gestural onsets: $ONSET\ LAG = V_{ONSET} - C_{ONSET}$; (4) lag between the gestural targets: $TARGET\ LAG = V_{TARGET} - C_{TARGET}$. Also, we analyzed the correlation between $C_{DURATION}$ and TARGET LAG. Also, we analyzed the correlation between $C_{DURATION}$ and TARGET LAG. Bayesian linear mixed models using the *brms* package v2.18.0 [13] in R v4.2.2 [14] were performed for the statistical analysis.

RESULTS: Figure 1 plots the relation between C DURATION (x-axis) and TARGET LAG (y-axis) across CV TYPE. C DURATION is not strongly correlated with TARGET LAG, showing only a slight upward trend. Notably, we observe the same pattern for all CV TYPE. To assess these results, we fit a series of Bayesian regression models to the data. We found evidence that variation in C DURATION impacts TARGET LAG, but the impact is small (β=0.82 [0.50, 1.15]). Crucially, however, we also found evidence that the way that variation in C DURATION impacts TARGET LAG is uniform across different types of CV in French (Cdur_Enchaînement β=-0.25 [-0.68, 0.18]; Cdur_Liaison β=0.40 [-0.09, 0.89]). Table 2 summarizes the results from Bayesian regression models for C DURATION, OVERLAP, ONSET LAG, and TARGET LAG. The statistical analysis reveals that there was no evidence for Enchaînement CV or Liaison CV being different from Onset CV in terms of four temporal intervals: C DURATION, OVERLAP, ONSET LAG, and TARGET LAG. The results indicate that Enchaînement CV and Liaison CV showed the same coordination as Onset CV.

DISCUSSION: The results of the present study provide evidence that resyllabified consonants are also timed in-phase with the following vowel, unlike [11] have found for Quebec French. Obtaining physiological data from EMA allowed us to examine the temporal coordination of gestures involving the articulation of external sandhi in French. Moreover, we make use of the concept of coordination to relate speech kinematics to the syllable structure. However, this resyllabification across words raises many questions—to be resolved—on the process of inter-gestural coordination. In future work, we will further investigate the temporal properties of the preceding vowel, which was also reported to be one of the acoustic characteristics preserving the contrast between the three sequence types. In addition, we will examine whether enchaînement C and liaison C maintain coordination with the preceding vowel.

Onset	Enchaînement	Liaison
/CV#**CV**/	/CV.**C**#**V**/	/CV.**CL**#**V**/
petit tamis /pəti # tami/ [pə.ti.ta.mi]	petite amie /pətit # ami/ [pə.ti.ta.mi]	petit ami /pəti # ami/ [pə.ti.ta.mi]

Table 1: Examples of three types of CV in French.

	Enchaînement – Onset	Liaison – Onset
C DURATION	β=-1.45 [-5.79, 2.89]	β=-1.71 [-6.03, 2.59]
OVERLAP	β=3.85 [4.31, 11.76]	β=-3.85 [-11.63, 4.04]
ONSET LAG	β=-10.51 [-22.50, 1.54]	β=4.99 [-6.09, 16.45]
TARGET LAG	β=-10.55 [-30.03, 8.68]	β=-1.61 [-20.48, 17.61]

Table 2: Summary of Bayesian linear mixed models

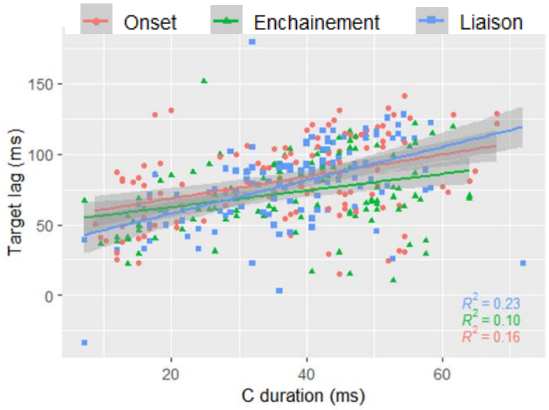

Figure 2: Target lag by C duration across CV

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