Prosodic position effects: strengthening for withstanding?

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Prosodic position effects (PP effects) include variations in the phonetic make-up of segments according to their position relative to prosodic prominences and boundaries. Past results have suggested that prosodic position effects target the contrastive phonetic properties of segments under prominence or close to strong prosodic boundaries (see [1,2] for a review). For instance, the lingual, laryngeal, nasal, or consonantal phonetic properties of domain-initial consonants (#C) have been found to be reinforced according to the strength of the preceding boundary (e.g. [3]). A maximization of acoustic contrasts in strong prosodic positions has also been found for vowels in initial position of strong prosodic domains. (e.g. [4,5]). In these studies, the articulatory or acoustic manifestation of PP effects have been ascribed to the idea of a strengthening of the segment properties as a way to enhance paradigmatic and/or syntagmatic contrasts in strong prosodic positions.

Further results suggest that rather than an additional reinforcement of contrastive properties, the observed effects of PP are the sign of a resistance against reduction in strong prosodic position. Indeed, less tongue twister errors have been found in pitch accented or phrase initial words ([6]) and less consonantal distortions are made after strong prosodic boundaries in some dysarthrias ([7]). Reduced overlap has also been described in prominent position and across strong prosodic boundaries in different structural configurations with targets and triggers straddling a boundary (#) (e.g. V#C [8]; C#V [9]; V#(C)V [10]; C#C [11]), while controversial results have been reported for coarticulation between adjacent segments at domain edges. Reduced overlap at the beginning of strong prosodic constituent has been found by [12] for German #CC sequences, and by[13] for English #NV sequence, while no effects are reported in [14] for #CC or in [9] and [11] for #CV. Reduction of coarticulation between segments in strong prosodic position can be interpreted as a way to reinforce syntagmatic contrasts between less overlapping segments, but also paradigmatic contrasts if reduced coarticulation make the segment more distinctive.

In this presentation, we will present recent results further supporting that prosodic strengthening can be interpreted as a way to withstand phonetic reduction in strong prosodic positions. Arguments are based on different studies on French vowels, using various methodologies, looking at the way PP effects modulate (a) coarticulation in post-boundary sequences, (b) duration dependent phonetic reduction, (c) phonetic variability across repetition, (d) acoustic discriminability of French vowels.

Study1 looks at variation in overlap in a post-boundary sequence ([15,16]). Anticipatory and carryover C-to-V coarticulatory effects are tested, and the structural relationship between the target and the trigger is manipulated (heterosyllabic V_1.C sequence vs. tautosyllabic V_1C and CV_1 sequences). Contextual effects of C, either alveolar (C_{ALV}=/t, d, z, s, l, n/) or uvular (C_{UV}=/R/), on the acoustic of V_1 =/a/ vowel are examined according to the prosodic position of the target vowel: in an Intonational Phrase initial position (IPi) or in a word-medial position (Wm). For IPi anticipatory coarticulation, the target /a/ vowel is sitting at the edge of the IP constituent (##V_1C and ##V_1.C), while for carryover coarticulation (##CV_1), the target is in the initial syllable of the domain (##CV_1). Speech material is extracted from two large corpora of natural French allowing for the study of 7000 tokens of /a/. Coarticulation is measured as F1 and F2 changes according to the context (C_{ALV} vs. C_{UV}). In all types of sequences, expected contextual effects (e.g. lower F1 in C_{ALV} vs. C_{UV} context) and prosodic position effects (higher F1 in IPi vs. Wm) are found. Crucially, this last effect appears to be stronger for V_1C and V_1.C, where /a/ is clearly more open in IPi, and weaker when the target /a/ is not in absolute initial position (i.e. CV_1). More interestingly, this study reveals some interactions between prosodic position and contextual effect showing *less coarticulation in IPi position for V_1C and V_1.C sequences* (but not for CV_1) with a greater reduction of coarticulation for V_1.C sequences. These results suggest that vowels immediately following an IP boundary withstands overlap with following consonants. Furthermore, the modulation of coarticulation by prosodic position informs us on the time window (and/or encoding unit) over which prosody adjusts the coordination between segments: this tuning does operate on sequences with less tightly specified coupling patterns such as heterosyllabic V.C, nucleus+coda VC. sequence, but not on a tightly coordinated tautosyllabic CV sequences.

Study 2 looks at duration dependent spectral reduction according to prosodic position. Formant frequency of /a/ vowels in a controlled consonantal context (/p_p/ and /p_s/) are examined according to the duration of the vowel in two domain final positions: in Intonational Phrase final position (IPf) vs. in a word final but IP medial position (Wf); and in two domain initial positions: in Intonational Phrase initial position (IPi) vs. in a word initial but IP medial position (Wi). In IPf position, the vowel is at the domain edge (CV#), while in initial position, the vowel is the second element of an initial syllable (#CV). Read productions of the test sentences are collected for four speakers, for a total of 180 tokens per position. Expected duration dependent reduction of F1 is found overall, with shorter vowels being less open. Crucially, *the relationship between F1 height and duration is found to depend on prosodic position*. While the opening of IP medial vowels, in both word-final and word-initial positions, is linked to its duration (r=.63 and r=.5, respectively), this relationship does not hold for vowels close to IP boundaries. IP final (CV#) vowels are globally lengthened and have a higher F1 than Wf. Their distribution in both spectral and temporal dimensions overlap that of Wf vowels, but contrary to Wf vowels the two dimensions are not related (r=.17). Vowels in the initial syllable of IP (IPi #CV) are not lengthened compared to Wi position and their F1 is not correlated with their duration (r=.16). The spatio-temporal tradeoff responsible for vowel reduction in speech is therefore affected by prosodic position. Vowels close to domain edges seem to be protected against duration-dependent phonetic reduction and show stable spectro-temporal specifications.

Study 3 follows-up on the idea that the resistance of prosodically strengthened segments may translate into more stable phonetic targets, and tests for this stability across multiple repetitions. Token-to-token variability of the vowel /a/ in the four prosodic positions described in study 2 above (IPf, IPi, Wf, Wi) is tested in the productions of four speakers. Forty five repetitions of the test sentences have been collected over 5 recording sessions over two weeks, with 9 repetitions of each condition per session. Variability is measured with a pair-wise variability index (PVI) computing the average differences in F1 between pairs of successive repetitions divided by the mean frequency of the pairs. For initial positions, PVI values vary according to speakers (p=.001) but no effect of prosodic position (IPi vs. Wi) nor interaction between speakers and position is found. For final positions, on the other hand, the speaker dependent PVI values (p=.01) interact with prosodic position (p=.005): *for two of the four speakers, IP final vowels show less token-to-token variability*. More speakers remain to be analyzed to confirm whether vowels targets are indeed more stable in IP final positions.

Last arguments supporting the view that PP effect contribute to withstand phonetic reduction comes from a 4th study looking at the acoustic discriminability among vowels within the French oral vowels system ([17]). Discriminability is assessed on the base of classification results of two types of classifiers: a linear discriminant analysis (LDA) based on the four formants frequencies, and a deep convolutional neural network (CNN) based on spectrogram pictures. Classifiers were trained using a set of 4500 vowels extracted from a large read speech corpus and the test set includes 720 exemplars of /i, y, e, ɛ, a, x, u, o, ɔ/ (with /x/=/ø, œ/) produced either in intonational phrase initial (IPi) or word initial (Wi) position. Results show that PP effects translate into a *better discriminability of vowels* (overall better classification rate) in IPi than in Wi with the two methods. More crucially, among the dimensions showing a better discriminability in IPi, *less confusions are found between peripheral and central vowels*. These results suggest that peripheral vowels are less reduced toward the center of the acoustic space in IPi position.

Taken together these results support the view that information about prosodic phrasing is available at the moment in the planning process when low-level adjustments of phonetic targets are implemented.

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