Acoustic and articulatory vowel variation as quality shift and increased variance in anticipatory and carryover vowel-to-vowel coarticulation

Andrea Deme[1,2], Márton Bartók[1,2], Tamás Gábor Csapó[2,3], Tekla Etelka Gráczi[2,4], Alexandra Markó[12,]

[1]*Eötvös Loránd University,* [2]*MTA-ELTE "Lendület" Lingual Articulation Research Group,*
[3]*Budapest University of Technology and Economics,* [4]*Research Institute for Linguistics HAS*
deme.andrea@btk.elte.hu

It is a commonly held fact that not only adjacent speech sounds but also transconsonantal vowels have an effect on each other, as the vowels in V_1CV_2 sequences are produced with one single underlying diphthongal gesture [7]. It is often hypothesized that the V-to-V coarticulation induced contextual variation of vowels is dependent on several factors, e.g., prosodic position, and vowel quality of the target V, prosodic position of the context/trigger V, and direction of coarticulation. Some previous studies in non-words showed evidence of an increased resistance to coarticulatory effects in prosodically strong positions, i.e., in lexically stressed ([3,6]; acoustic data) and pitch-accented syllables ([1]; articulatory data). Recent real-word studies, however, also revealed that if captured in parallel, acoustic and articulatory resistance tendencies may also be highly different both in magnitude and nature [2]. For prosodically conditioned coarticulatory aggression in V-to-V coarticulation, articulatory data showed no support [1]. As for the direction of coarticulation, carryover coarticulation was found to be stronger than anticipatory both in articulation [1,8] and acoustics [6].

Note that most of the above studies captured V-to-V induced "contextual variation", in quality differences of coarticulated and non-coarticulated tokens. Contextual variation, however, may just as well be interpreted as actual variation, i.e., "dispersion" of vowel tokens observed in the acoustic and articulatory spaces, which is not yet explored under the conditioning effect of the above factors. Furthermore, limited amount of available results warrants for further exploration of the question if coarticulatory resistance/aggression of the same tokens in the same utterances is detectable both in acoustics and articulation. It is important to note here, that according to a well-known (but in some respect, understudied) hypothesis, variability/dispersion of V realizations is also affected by the density of the vowel space [4]; therefore, it is safe to assume that none of the effects claimed to influence V-to-V induced variability generalize automatically across languages.

In the present study we analyzed synchronously collected acoustic and EMA data and retested if the effect of V-to-V coarticulation depended on directionality (anticipatory/carryover coarticulation), and examined if coarticulatory resistance and aggression are conditioned prosodically. As opposed to previous studies, we captured coarticulatory effects (or contextual variation) in two ways: i) as acoustic and articulatory differences of coarticulated and non-coarticulated tokens, and ii) as dispersion of corresponding acoustic and articulatory parameters. We analyzed the /i u/ point vowels in 9 speakers of Hungarian, in the context of the minimally constrained labial stop /p/ in nonsense /pVpVpVpV/ sequences (min. 6 repetitions per speaker) in pitch-accented (ACC) and unaccented (UN) syllables, in coarticulating and non-coarticulating contexts. I.e., to analyze, for instance, /i/ targets, we used /p**i**$_{\mathrm{ACC}}$pu$_{\mathrm{UN}}$pupu/, /p**i**$_{\mathrm{ACC}}$pi$_{\mathrm{UN}}$pipi/, /pip**i**$_{\mathrm{UN}}$pu$_{\mathrm{UN}}$pu/, /pip**i**$_{\mathrm{UN}}$pi$_{\mathrm{UN}}$pi/, /pu$_{\mathrm{ACC}}$p**i**$_{\mathrm{UN}}$pipi/, /pi$_{\mathrm{ACC}}$p**i**$_{\mathrm{UN}}$pipi/, /pupu$_{\mathrm{UN}}$p**i**$_{\mathrm{UN}}$pi/, and /pip**i**$_{\mathrm{UN}}$pi$_{\mathrm{UN}}$pi/ (**target**, trigger), similarly to [1,5,6].

In accordance with previous studies, we obtained F_1 and F_2 values at the onset, offset, and temporal midpoint of target vowels, and measured and averaged the horizontal (*x*-axis) position of the backmost two tongue body sensors as "dorsum" data [1,2]. Position data were normalized to the maximum and minimum *x*-axis displacement of the given sensor for each speaker. To quantify variability, we calculated relative SD (RSD; SD/|mean|×100) for vowel midpoint data (called *dispersion,* where the greater the value the greater variability is in realization of a given target), and distances of coarticulated and non-coarticulated tokens measured at the vowel edge which was located closer to the trigger vowel (called *distances,* where the greater the value, the greater the difference is between target vowel qualities). Data were tested with linear mixed models.

Dispersion data in general revealed greater variation in /u/ than in /i/ in both domains, and any further effects we found was present only in this (presumably less resistant) vowel, /u/. Here, anticipatory effects were shown to be stronger than carryover (as anticipatory coarticulation induced greater variance in targets) both in articulation and acoustics. In accented syllables, we observed increased coarticulatory strengthening (less variance in accented targets than in unaccented ones) and increased coarticulatory aggression (greater target variance induced by accented triggers than that of induced by unaccented triggers), in both domains alike (Fig 1, 2). In **distances** data, however, we found very different trends. Here, carryover effects were found to be stronger than anticipatory (as carryover coarticulation induced greater centralization than anticipatory), and results diverged for articulation and acoustics showing greater centralization for /i/ in acoustics, and for /u/ in articulation. Further, we found no difference between accented and unaccented syllables (Fig 3), which contradicts the prosodic conditioning of coarticulatory resistance and aggression hypotheses.

As results were not conclusive for the two tested measures of contextual vowel variation with respect to none of the effects hypothesized, we propose that prosodically conditioned coarticulatory resistance and aggression of vowels needs further exploration to clarify if resistance may best be conceptualized as i) contextual (in)variance that can be grasped in dispersion measures, or rather ii) increasing/decreasing capability of adaptation in quality, which is reflected in distance measures.

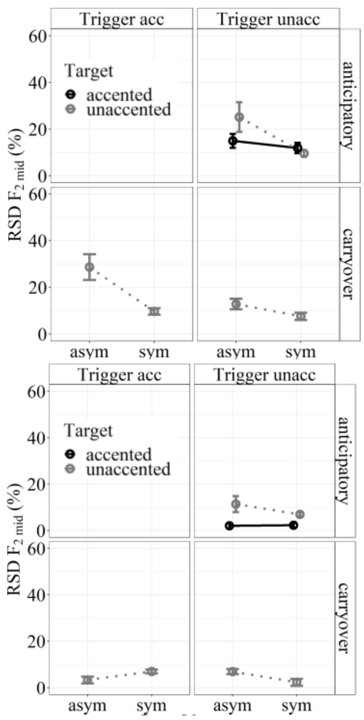

Figure 1: Acoustic variation (dispersion) of F2 midpoint data in /u/ (above) and /i/ (below)

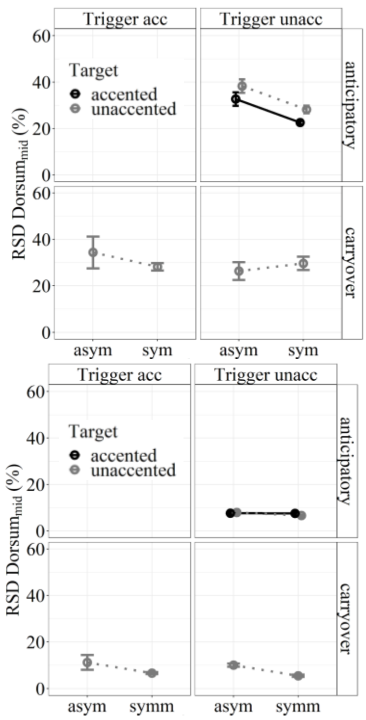

Figure 2: Articulatory variation (dispersion) of horizontal dorsum displacement in /u/ (above) and /i/ (below)

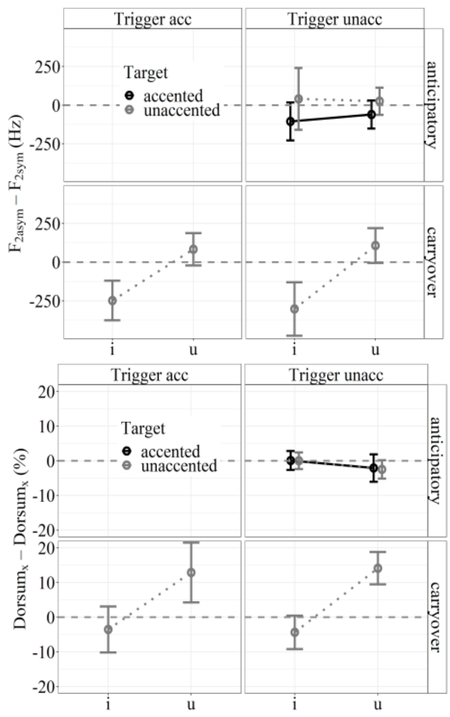

Figure 3: Acoustic (above) and articulatory (below) distances of coarticulated and non-coarticulated tokens

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