Investigating Conflicting Aerodynamic Requirements in CC Clusters

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Previous research suggests that C_1C_2 timing depends on cluster composition as well as on prosodic alternation, yet the interaction of these two factors has rarely been investigated systematically (e.g. Bombien *et al*. 2013; Byrd 1996; Cohn and Chitoran 2009; Kühnert *et al*. 2006). The present study brings together these two strands of research and investigates the articulatory timing of Polish onset clusters in terms of conflicting aerodynamic requirements in stop and nasal onset clusters (i.e. /pC/ vs. /mC/, respectively).

An extensive list of C_1C_2 organization studies proposes that manner of articulation of both C_1 and C_2 affect how cluster consonants are temporally organized with each other: Specifically, consonant clusters with plosive C_1 have been shown to allow for relatively less gestural overlap presumably because the release is crucial for the perceptual recoverability of stops. At the same time less consonantal overlap has been shown in clusters containing a plosive C_2 than in clusters containing a sibilant or lateral C_2 (Bombien *et al*. 2013; Byrd 1996; Cohn and Chitoran 2009; Kühnert *et al*. 2006). Overall, not much is known about the factors conditioning different consonant overlap patterns, and how different overlap patterns are actually implemented in terms of articulatory coordination.

Further factors which seem to affect C_1C_2 organization are prosodic variation and different aerodynamic requirements if nasals are involved. First, clusters in words in unaccented position show increased articulatory overlap compared to the same cluster in accented position (e.g. Bombien *et al*. 2013). Secondly, clusters with C_2=/n/ consistently showed less articulatory overlap than the same clusters with C_2=/l, s/ (Kühnert *et al*. 2006; for an interaction of prosodic variation and aerodynamic requirements see Bombien *et al*. 2013). This indicates that in the production of stop+/n/ clusters the preservation of the stop release and the lowering of the velum for the nasal are temporally in conflict with each other. To avoid this conflict, the stop and the nasal overlap less than stop+/l, s/ since non-nasal consonant may be produced during labial closure without interfering necessary aerodynamics. However, Bombien's data were limited to very few German clusters. In this paper we test whether these effects generalize cross-linguistically to Polish as a language that has generally a different coarticulation pattern from German, with clusters being generally less coarticulated. We further test whether generally conflicting aerodynamic requirements predict a particular coarticulation pattern and imply a lesser flexibility of this coarticulation pattern under prosodic variation.

We examine in this paper a range of labial+coronal onset clusters with C_1={/p/, /m/} (i.e C_1 varied in terms of perceptual recoverability constraints) and C_2={/ʃ/, /l/, /n/}. The hypotheses for the present study depend on manner of C_1. The temporal coordination of stop release and velic lowering is crucial for the production of /pn/ clusters: if both consonants are narrowly coordinated, then nasality would interfere aerodynamically with the acoustic stop burst; hence, the perceptual recoverability of /p/ would be compromised. Since this is not the case for the remaining /pC/ clusters, we expect in /pn/ less C_1C_2 overlap than in /pl, pʃ/, and we predict that /pn/, in contrast to the other clusters will not change its coarticulatory pattern under prosodic variation. Regarding /mC/ clusters, /mʃ/ should be timed further apart than /ml/ or /mn/ due to conflicting aerodynamic requirements. A lowered velum for /m/ would cause a lack of turbulence during /ʃ/ due to insufficient intraoral air pressure. In sum, since conflicting aerodynamic requirements are assumed to block an increase in coarticulation in unaccented position, we hypothesize for both sets (i.e. /pC/ and /mC/ clusters) an interaction of C_2 and Accent. For the C_1=/p/ set, the interaction should be carried by /pn/, for the C_1=/m/ set, it should be carried by /mʃ/ in that these

clusters do not change their coarticulation with accent.

We recorded articulography (EMA) data of six native speakers of Polish. They produced four repetitions of disyllabic target words beginning with /pn, pl, pʃ/ and /mn, ml, mʃ/, embedded in a carrier phrase (n=275). Phrasal accent was elicited either on the target word (accented) or on the phrase initial word (unaccented). All target syllables bore word-level stress. As overlap measure we used Plateau Lag as the temporal distance of C_1 target release and C_2 target achievement. We calculated two separate mixed models for /pC/ and /mC/-clusters with dependent variable Plateau Lag, random factors Speaker and Cluster (Repetition had no effect), and fixed factors were C_2 and Accent.

For /pC/ clusters we predicted an interaction between C_2 and Accent since /pn/ was not expected to differ in accented and unaccented target words. Qualitatively our prediction concerning /pn/ was confirmed (Fig. 1, right): /pn/ shows lesser variation as a function of Accent compared to /pl, pʃ/. However, the statistical interaction failed to reach significance. For /mC/ clusters we hypothesized an interaction between C_2 and Accent on Plateau Lag since C_1C_2 overlap of /mʃ/ was not assumed to differ in accented and unaccented target words. For this group the conducted mixed model revealed the expected interaction ($\chi^2[2]=11.293$, $p<.01$). However, contrasting our prediction this interaction was carried by cluster /ml/ instead of /mʃ/. In fact, /mʃ/ ($p<.001$) and /mn/ ($p<.001$) had decreased Plateau Lags in the unaccented condition (Fig. 1, left).

In sum, this work suggests contra previous work that conflicting aerodynamic requirements do not alone predict C_1C_2 timing. This is particularly evident in clearly shortened Plateau Lags found for /mʃ/ in spite of a possible aerodynamic conflict. For /pn/ the predicted effect was only obtained at a qualitative level. These results challenge Bombien *et al*.'s claims that stop-nasal clusters and, by our extension of his argument, any cluster with conflicting aerodynamics are generally cross-linguistically dispreferred. On the other hand, we did find that clusters differ in their flexibility under prosodic variation: the comparatively short CC lag of accented /ml/ does not decrease any further for unaccented /ml/, suggesting something like a floor effect for plateau lag, possibly indeed for perceptual reasons. In sum, our work suggests that a complex interaction of language and cluster-specific effects determine C-to-C coarticulation, rather than general aerodynamic requirements.

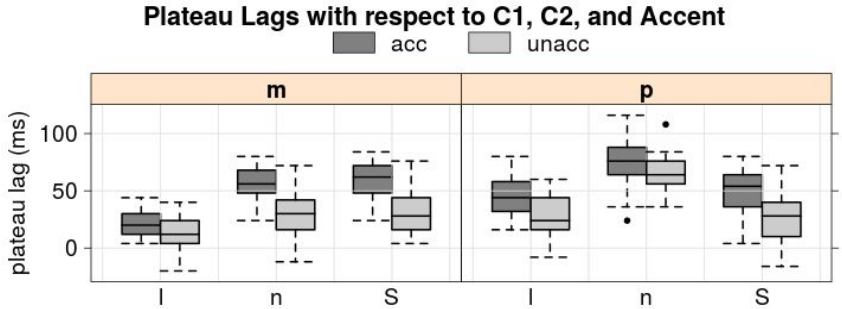

Figure 1: Plateau lags (in ms) are given for C_1=/m/ (left) and C_1=/p/ (right) with respect to C_2 and Accent.

References

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