Anticipatory and carryover coarticulation share a similar origin: evidence from child speech

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Articulatory gestures of neighboring segments in a speech stream are coproduced (Fowler, 1980). These coarticulatory effects do not only occur between adjacent segments but can span wide ranges in both the anticipatory and carryover direction (Hardcastle & Hewlett, 2006).

In our previous kinematic studies examining developmental differences in vocalic anticipatory coarticulation in children, we had found a gradual decrease of intra- (CV; Noiray, Wieling, Abakarova, Rubertus, & Tiede, 2019) and inter-syllabic coarticulation degree (əCV; Rubertus & Noiray, 2018) with age. We interpreted the strong vocalic anticipation in young children as evidence for broader vocalic activation than in adults resulting in more coproduction (cf. Nittrouer, 1993). However, adults' inter-syllabic and all cohorts' intra-syllabic coarticulation degree depended on the identity of the consonant.

To our knowledge, vocalic carryover effects have barely been addressed in child speech (e.g., Flege, 1988). Yet, knowledge about its implementation in developing speech should shed new light on the debated question whether anticipatory and carryover coarticulation originate from a single control mechanism or whether the first is planned while the latter results from mechano-inertial factors (Recasens, 1984). If anticipatory and carryover coarticulation share a common origin and it is indeed mainly the width of vocalic activation that decreases across age, carryover coarticulation should follow the same developmental trajectory as found in our previous work on vocalic anticipation, with weaker effects the older the children are. If however, different control mechanisms underly the two coarticulatory directions and inertial properties in contrast to planning processes do not change with development because they need not to be learnt (Flege, 1988), the developmental differences found in anticipatory coarticulation may be absent or weaker in carryover coarticulation.

We recorded 62 native German children (3y, 4y, 5y, & 7y) and 13 adults using SOLLAR, a child-friendly recording platform combining ultrasound tongue imaging, acoustic, and video data (Noiray, Ries, & Tiede, 2015). In a repetition task, participants produced C_1VC_2ə pseudowords (C = /b/, /d/, /g/, V = /i/, /y/, /u/, /a/, /e/, /o/, $C_1 \neq C_2$) preceded by the article /aɪnə/. These data are the same as in our analyses on anticipation. With generalized additive modeling (GAM; Wood, 2017) we investigated the vowel-induced horizontal displacement of the tongue dorsum's highest point and its interaction with age and consonant identity at four time points within the utterances' last syllable: start of C_2, midpoint of C_2, start of ə, and midpoint of ə.

In every age cohort, the vowel affected the tongue dorsum position during the following consonant and schwa significantly ($p<0.001$). Figure 1 illustrates this by depicting two examples of participants' tongue contours during the temporal midpoint of /g/ either following the vowel /i/ (in red) or the vowel /u/ (in green). Both participants produce /g/ following /i/ more front than /g/ following /u/. The strength of the vocalic carryover effect varied with consonant context: Vowels followed by /b/ were more strongly perseverated than those followed by /g/ (only three-year-olds did not show this effect). VCə sequences with C = d exhibited the least vocalic carryover coarticulation in all cohorts. Results from across-cohort analyses revealed a decrease in coarticulation degree in /g/ and /b/ contexts with increasing age (the greater difference between red and green tongue contours in the 4-year-old (left plot) than in the adult (right plot) in Figure 1 is an example of this decrease). In the alveolar context, children's tongue dorsum contributed more to moving the tongue tip front during the consonant than adults'. This resulted in the opposite pattern of less vowel perseveration in younger than in older participants during the temporal domain of the consonant but again slightly more coarticulation for younger than older participants during the final schwa.

While the alveolar context provides insights into the development of independent control of the tongue tip and the tongue dorsum, the similarities between the overall decreasing degree of coarticulation here and in the previous studies on anticipatory coarticulation suggest one common control mechanism to guide both coarticulatory directions. We suggest it to be the coproduction of simultaneously active speech gestures which decreases across childhood in both directions possibly because of the maturation of inhibitory control responsible for accurate selection and de-selection of articulatory gestures (cf. Tilsen, 2016).

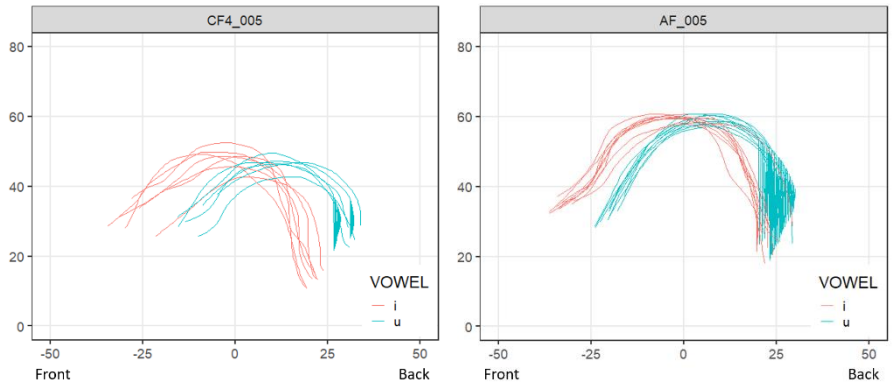

Figure 1. Examples of tongue contours during the midpoint of /g/ after /i/ (in red) and /u/ (in green) for a 4-year-old (left plot) and an adult (AF_005).

References

Flege, J. E. (1988). Anticipatory and carry-over nasal coarticulation in the speech of children and adults. *Journal of Speech and Hearing Research*, *31*(December), 525–536. doi: 10.1044/jshr.3104.525

Fowler, C. A. (1980). Coarticulation and theories of extrinsic timing. *Journal of Phonetics*, *8*(1), 113–133.

Hardcastle, W. J., & Hewlett, N. (2006). *Coarticulation: Theory, data and techniques*. Cambridge: Cambridge University Press.

Nittrouer, S. (1993). The emergence of mature gestural patterns is not uniform: Evidence from an acoustic study. *Journal of Speech, Language, and Hearing Research*, *36*(5), 959–972. doi: 10.1044/jshr.3605.959

Noiray, A., Ries, J., & Tiede, M. (2015). Sonographic & Optical Linguo-Labial Articulation Recording system (SOLLAR). *Proceedings of Ultrafest VII, Hong Kong*, 8–9.

Noiray, A., Wieling, M., Abakarova, D., Rubertus, E., & Tiede, M. (2019). Back from the future: non-linear anticipation in adults' and children's speech. *Journal of Speech, Language, and Hearing Research*, *62*(8S), 3033–3054. doi: 10.1044/2019_JSLHR-S-CSMC7-18-0208

Recasens, D. (1984). Vowel-to-vowel coarticulation in Catalan VCV sequences. *The Journal of the Acoustical Society of America*, *76*(6), 1624–1635. doi: 10.1121/1.391609

Rubertus, E., & Noiray, A. (2018). On the development of gestural organization: A cross-sectional study of vowel-to-vowel anticipatory coarticulation. *PloS One*, *13*(9), e0203562. doi: 10.1371/journal.pone.0203562

Tilsen, S. (2016). Selection and coordination: The articulatory basis for the emergence of phonological structure. *Journal of Phonetics*, *55*, 53–77. doi: 10.1016/j.wocn.2015.11.005

Wood, S. N. (2017). *Generalized additive models: an introduction with R*. Chapman and Hall/CRC.