Development of coarticulation: comparing modalities in beginner readers

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The present study investigates the interaction between reading proficiency and speech production for different speech modalities (read vs. repeated speech) in beginner readers (second and third graders). The considered speech production parameter is anticipatory coarticulation degree (CD), i.e. the degree of temporal overlap between speech gestures of either consecutive CV or non-consecutive vowel (əCV) sounds. The development of children's CD has been investigated in a number of studies (e.g., Noiray, Abakarova, Rubertus, Krüger, & Tiede, 2018; Rubertus & Noiray, 2018; Zharkova, Hewlett, & Hardcastle, 2012). Most studies have focused on age-related differences in coarticulatory organization, which leads to the consideration that coarticulatory development is mostly a question of maturation of the speech motor system. Only recently have a few studies proposed a skill-based approach to coarticulation development in addition to the classic age-based analysis: Noiray et al. (2019) have demonstrated that higher levels of phonological awareness correlated with lower CD in preschoolers and first-graders. Reading proficiency has also been linked to speech production parameters: more proficient readers have been shown to exhibit more speech movement stability (measured as lip aperture variability – Saletta, Goffman, & Brentari, 2016) and lower degrees of anticipatory coarticulation (Popescu & Noiray, 2019) in repeated speech. Here, we extend previous research by addressing inter-speaker CD variability and its correlation with reading proficiency in read speech, as well as intra-speaker CD differences between speech modalities.

Hypothesis: Coarticulation degree in children is subject to intra- and inter-speaker variability: intra-speaker variation is prompted by speech modality manipulation, inter-speaker variation reflects differences in reading proficiency.

Participants: 32 native German speakers (16 females, 16 males) aged between 7;03 (Y;MM) and 9;05 years (mean: 8;03) all living in the Potsdam area (Brandenburg, Germany).

Test stimuli: 30 different disyllabic pseudo-words (**CV**Cə) embedded in a carrier phrase following the article /aɪnə/. Target vowels corresponded to one of the five tense vowels /i/, /e/, /a/, o/, /u/ while C_1/C_2 were one of three /b/, /d/, /g/, but never the same (*e.g. eine bude, eine dage).*

Task: The visual and audio stimuli were presented in two sequential tasks. Participants first read the stimuli off a screen. In the second part they were instructed to repeat pre-recorded stimuli. Both tasks consisted of two repetitions per trial presented in two randomized blocks.

Articulatory/Acoustic data: Articulatory data was recorded using ultrasound tongue imaging (Sonosite edge, 48Hz) which provides kinematic data of lingual speech gestures. The acoustic data was recorded using a Sennheiser microphone (48Hz).

Reading assessment: Children's reading proficiency was addressed with the SLRT-II (Moll & Landerl, 2010), a standardized test for German assessing the number of correctly read (non)words within one minute. The results of the nonword reading proficiency assessment (Fig. 1) show age and reading proficiency are not correlated ($r(30) = .11$, $p = 0.56$) which supports a skill-based investigation of coarticulation development.

Data analysis: CD is calculated as a regression between the position of the tongue during the temporal midpoints of the segments (C_1 and V for intra-syllabic coarticulation and ə in /aɪnə/ and V for inter-syllabic coarticulation). The midpoints of the segments are determined based on the acoustic data.

Predictions: Two sets of predictions are considered. First, by comparing speech production across modalities, we expect coarticulation degrees to be higher in repeated than in read speech because of the clear separation of phoneme-sized units in relatively transparent scripts like German leading to the use of grapheme-phoneme-level correspondences (Brown & Deavers, 1999). This would corroborate previous research showing that spontaneous speech is more strongly coarticulated than listed (i.e. read) speech (Krull, 1989). The second set of predictions pertains to the correlation between reading proficiency and coarticulation degree within modalities. For repeated speech, we expect better readers to exhibit lower degrees of coarticulation, reflecting a gain in phonemic awareness (Popescu & Noiray, 2019). The case of read speech is less straightforward. We expect a shift (see Fig. 2 yellow dotted line) in patterns depending on reading fluency. Beginner readers of transparent scripts use grapheme-phoneme correspondences to parse words and nonwords grapheme by grapheme (alphabetical strategy, e.g., Brown & Deavers, 1999; Ehri, 2005). With increasing experience and practice decoding gets faster and reading becomes more fluent. For these *decoding readers*, we therefore expect an increase of CD with reading fluency improvement. Once the alphabetical strategy is overcome, *advanced readers* process simple nonwords globally (e.g., Ferrand, 2000) and CD in read aloud speech is expected to be comparable to repeated speech in that it decreases with better reading proficiency. The predictions are schematized in Fig 2.

Preliminary Results: First analyses do not support modality-based differences in CD but point towards a negative correlation between reading proficiency and CD independently of modality.

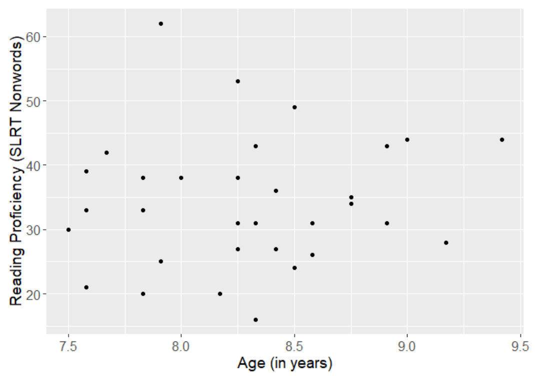

Figure 1. SLRT II nonword reading scores plotted over age.

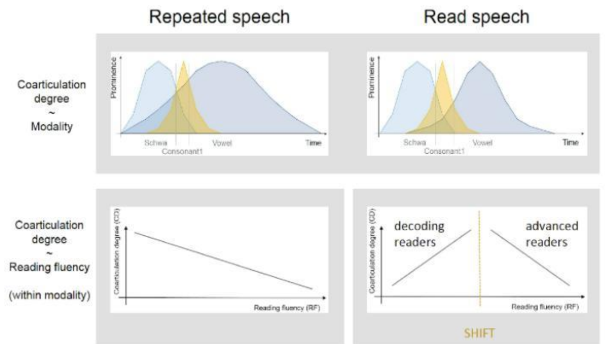

Figure 2. Predictions for CD as a function of speech modality.

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