Articulatory strategies and coarticulatory patterns across age

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Previous research has found stronger effects of the upcoming vowel on the tongue configuration during consonant production in CV sequences in developing speech as compared to adult speech (Nittrouer, Studdert-Kennedy, & Neely, 1996; Noiray et al. 2018). These effects have been attributed to both immature control of gestural coordination (Tilsen, 2018) and under-differentiated articulatory organization of consonant gestures (Nittrouer, 1996) but the independent contribution of each of these factors into lingual coarticulation patterns in developing speech has not been demonstrated. This work tests the hypothesis that age-related differences in coarticulatory patterns are related to developmental changes in articulatory strategies using ultrasound data analysis and task dynamical computational simulation.

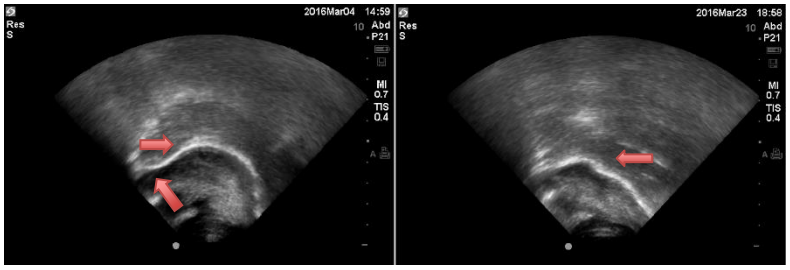

Figure 1 The midsagittal ultrasound image of the tongue contour at the temporal midpoint of the alveolar stop /d/ in the context of /u/ in an adult female (on the left) and a 3-year-old female (on the right). The grey circle indicates the anterior part of the tongue.

To test for the existence of differences in articulatory strategies involving tongue articulators (i.e. tongue body and tongue tip) in preschooler's speech as compared to that of adults we first studied the experimental ultrasound data collected from German preschoolers (3 to 7 years of age) and adults who produced CV syllables consisting of /d, z/ and /i:, e:, y:, u:, o:, a:/. Previous studies of this data set have reported a higher degree of coarticulation in children than in adults (Noiray et al. 2018; Noiray et al. 2019). An exploratory analysis of tongue shapes showed that children use different strategies to produce alveolar consonants. For example, during /d/ production, while adults produced an alveolar constriction by moving back the tongue body (TB) and raising the tongue tip (TT), children relied instead on the TB moving forward to create the alveolar closure (Fig.1). A subsequent quantitative analysis using modified curvature index (Dawson, Tiede & Whalen, 2016) confirms that the behaviour of the anterior part of the tongue is more complex in adult productions than it is in children's productions (Fig.2).

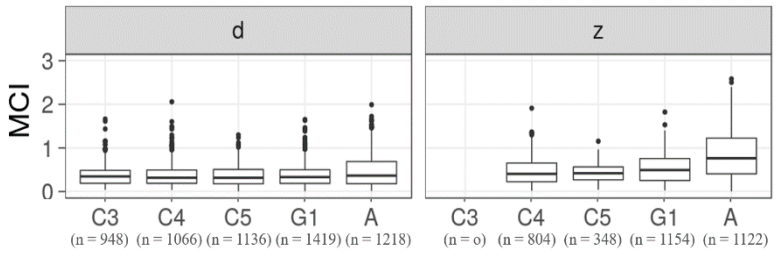

Figure 2 Modified curvature index (MCI) of the most anterior 20 points on the tongue contour that represent the anterior part of the tongue for five age groups. The higher curvature values the more complex is the shape.

Next, to study the role of articulatory strategies in age-related differences in coarticulation patterns we simulated the same natural speech data in Task Dynamic application (Nam et al. 2004), a computer implementation of the linguistic gestural model (Browman and Goldstein, 1992) and the Task Dynamic model (Saltzman and Munhall, 1989). To simulate the child-like articulatory strategies several configurations were tested: 1) the relative weights of the articulators contributing to the TT gestures were manipulated, 2) the default settings for alveolar consonants that include both TT and TB gestures were changed to exclude the TB gestures, and 3) the default settings for alveolar consonants were changed to exclude the TT gestures

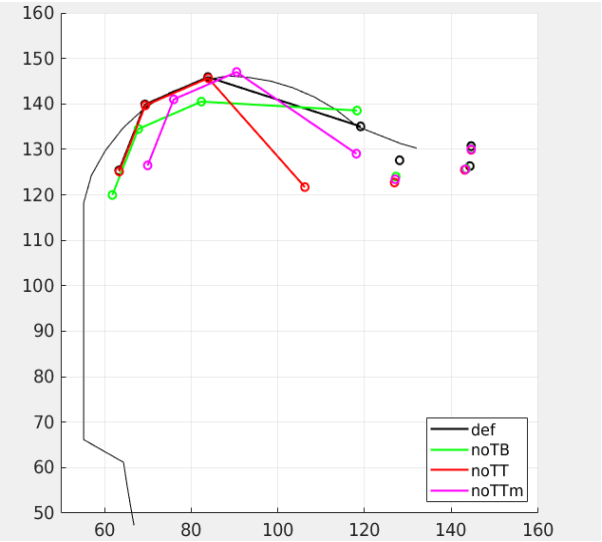

Figure 3 An example of simulated tongue contours during /d/ constriction (in /u/ context). The back of the tongue is on the left side. The tongue shape resulting from default settings (def) is shown in black, the one without TB gesture specified for alveolar stop (noTB) is shown in green, the one without TT gesture specified for alveolar stop (noTT) is shown in red. The simulated shape for the configuration without TT gesture specified for alveolar stop (noTT) and the target for TB gesture changed to a fronter one is shown in magenta.

while the target location for the TB constriction gesture was changed to a fronter one. The first two configurations failed to replicate child-like articulatory strategies. However, the configuration where the TT gestures for the alveolar constriction were removed and the target for the TB constriction location was fronted resulted into the simulated tongue shapes (Fig. 2) similar to those observed for children in the empirical data (see Fig. 1). Finally, the same configuration resulted in a higher amount of CV coarticulation than observed with the default settings, replicating the age differences in coarticulation patterns found in the empirical data. The results suggest that in alveolar consonant production, children rely on articulatory strategies that do not require a highly differentiated control over tongue's functional subparts. Importantly, these developmental differences in articulatory strategies result in differences in coarticulatory patterns, providing evidence for a strong link between articulatory organization of lingual gestures and coarticulation amount, and suggesting that any account of age-related changes in coarticulation patterns should include refinement of articulator strategies along with the maturation of coordinative control. Further research is being conducted to explore the potential reasons for age differences in articulatory strategies, such as motor control maturation and vocal tract growth.

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