

## Voiceless alveolar stop coarticulation in typically developing 5-year-olds and 13-year-olds

Typically developing children aged between 3 and 5 years old have been reported to anticipate the tongue position for the following vowel at the offset of stop consonants, in a very similar way to adults (Sussman et al., 1992; Noiray et al., 2013). However, at an earlier time point, namely at mid-closure of the alveolar stop, 5-year-old children were shown in a recent ultrasound study (Zharkova et al., 2015) to have less evidence of lingual coarticulation from the following contrasting vowels than adolescents. In the present study, measures of tongue shape were applied to compare coarticulation at the closure offset across the same two groups of speakers, ten 5-year-old children and ten 13-year-old adolescents, speaking Scottish Standard English. The study aimed to establish whether by the closure offset 5-year-olds are able to adjust the tongue shape to the following vowels to the same extent as adolescents.

The consonant /t/ was produced in CV syllables with the vowels /i/ and /a/ in a carrier phrase, with five repetitions of each target. The ultrasound data were recorded at the frame rate of 100 Hz, synchronised with the acoustic signal. The transducer was hand-held by the experimenter. The measures were the same as those used in Zharkova et al. (2015), with  $LOC_{a-i}$  quantifying the location of bunching along the tongue curve, and Dorsum Excursion Index (DEI) assessing the extent of tongue bunching. Linear mixed models with speaker as a random effect were used for inferential statistical analyses. Both groups had a significant vowel effect on DEI. There was no significant interaction of age and vowel in the model on DEI including both age groups, i.e., no difference in size of effect across groups. The adolescents had a significant vowel effect on  $LOC_{a-i}$ , while the 5-year-olds did not have an effect.

These results show that by the end of /t/ closure adolescents raise the tongue dorsum and modify the bunching location within the tongue curve in order to coarticulate the alveolar stop with the following vowels. By contrast, 5-year-old children even by the end of the closure do not consistently adjust the bunching location to accommodate the tongue shape to that of the upcoming vowel, but instead use dorsum raising alone. The results extend the findings from Zharkova et al. (2015), showing further developmental immaturities in 5-year-olds' productions. The lack of coarticulation by the younger children on  $LOC_{a-i}$ , a measure that can capture coordinated action of the front and the back of the tongue in anticipation of the vowel, suggests that the 5-year-olds may lack the extent of functional tongue differentiation that is demonstrated by the adolescents. The findings add to the growing pool of evidence that typical developmental patterns of vowel-on-consonant coarticulation are segment-specific (e.g., Sussman et al., 1999; Reidy 2015; Zharkova et al. 2015), and driven by the development of motor control. Future work will include carrying out analyses of tongue shape data from children aged over 5 years old, in order to establish the time course of the tongue differentiation development.

## References

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