

## Acoustic cues to coda voicing contrasts in Australian English-speaking pre-schoolers

In many languages including English, contrasting voiced oral stops (/b, d, g/) with their voiceless counterparts (/p, t, k/) is critical for differentiating words (e.g., **dog** vs. **do**ck****). While an extensive body of research has focused on stops in word-initial position, only limited information is available about the acoustic correlates of voicing contrasts for coda stops, and this is especially true for children's speech. The voicing contrast in English codas is primarily realized by means of the duration of the preceding vowel, closure duration, the presence of irregular pitch periods (IPP) at the end of the preceding vowel, and a voice bar (VB) during the closure [1, 2, 3]. Although these acoustic cues are found in children's speech from 1;6 years, they are only variably realized by the age of 3 years [4, 5, 6]. This then raises the question as to when children can produce these cues to voicing in an adult-like way at all places of articulation (PoAs). The present study therefore examined the acquisition of voicing contrasts in monolingual Australian English-speaking pre-schoolers. We predicted that children would systematically make voicing contrasts using vowel duration and closure duration, but with longer durations compared to adults. We also hypothesized that, like adults, children would use fewer VB and more IPP for voiceless stops than voiced stops.

A total of 20 adults ( $M = 28y$ ) and 20 children ( $M = 4;10y$ ) took part in the study. The stimuli consisted of 18 CVC words contrasted for voicing and PoA in coda position and crossed with three vowels. Participants repeated each target word five times in utterance final position (e.g., "See this **dog**"), for a total of 90 tokens per participant. A total of 1800 tokens were recorded per group. Vowel duration (VD) and closure duration (CD) preceding the coda consonants /b, d, g, p, t, k/ were measured and fitted in two linear mixed-effects models. Along with the durational cues, the presence of irregular pitch periods (IPP) at the end of the preceding vowel and the presence of a voice bar (VB) during closure were identified and fitted in two generalized linear mixed-effects models. All models included Group, Voicing and PoA as fixed factors, with words and participants as random intercepts, and random slopes for Voicing and PoA by participants.

There were main effects of Voicing and Group on VD ( $p < .001$ ) and CD ( $p < .001$ ), confirming our hypothesis that the voicing distinction would be realized at all 3 PoAs. As hypothesized, children had longer VD and CD than adults. Significant interactions for Voicing and Group (VD:  $p < .001$ ; CD:  $p < .001$ ) showed that the difference between voiced and voiceless stops was larger for children than adults (Figures 1 & 2). In addition, there were main effects of Voicing and Group on IPP ( $p < .001$ ) and VB ( $p < .001$ ), as well as significant interactions between these two factors (IPP:  $p < .001$ ; VB:  $p < .001$ ). Like adults, children used IPP for voiceless stops (Figure 3) and VB for voiced stops (Figure 4). However, children produced fewer instances of IPP for voiceless stops and VB for voiced stops than adults.

In sum, this study shows that, although 4-year-old children can distinguish voicing in coda stops at all places of articulation, their acoustic realizations of these contrasts are not yet adult-like. This suggests that children may find it challenging to master the absolute duration of these cues. The present findings provide a much-needed benchmark for evaluating control of coda voicing in populations for whom these contrasts are reported to be challenging, such as children with hearing loss [7].

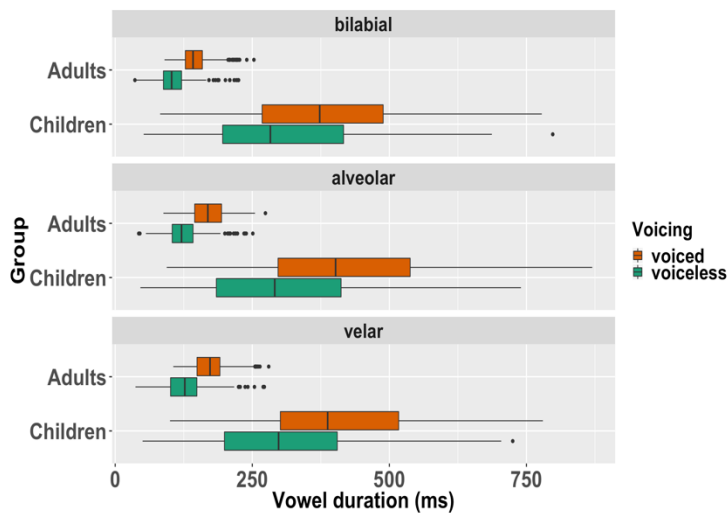


Figure 1. Vowel durations for voiced and voiceless stops at all PoAs by adults and children

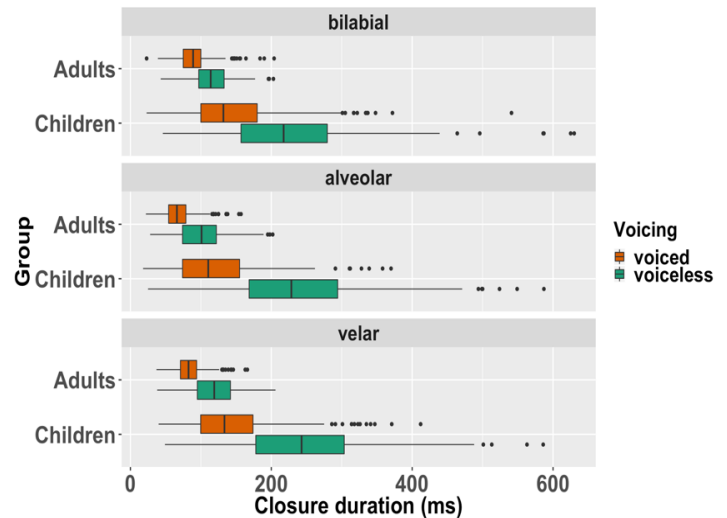


Figure 2. Closure durations for voiced and voiceless stops at all PoAs by adults and children

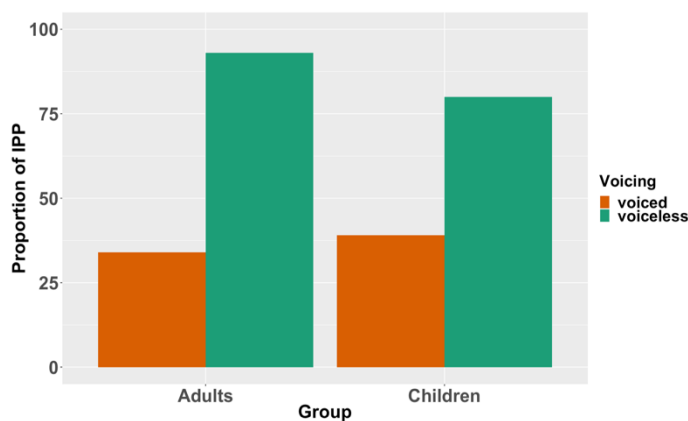


Figure 3. Percentage of items with irregular pitch periods for voiced and voiceless stops by adults and children

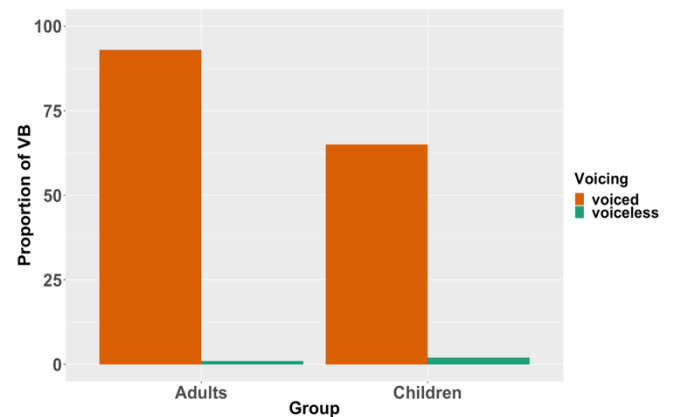


Figure 4. Percentage of items with a voice bar for voiced and voiceless stops by adults and children

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