Consonants and consonant sequences requiring the coordination of multiple lingual articulators are typically acquired late by children. While English-speaking adults typically produce /l/ with both an anterior and a posterior constriction, English-learning children often produce /l/ using only a single anterior constriction (Lin & Demuth, 2015). It is well established that consonant clusters, generally, are prone to simplification in early attempts (e.g., Goad & Rose 2004, Gerlach 2010).

This study uses linked audio and ultrasound data to illuminate children’s gestural coordination in consonant clusters involving /l/, in the context of the broader question of how the articulatory challenges of such sequences relate to differences in cluster production between children and adults. The specific hypothesis tested in this study is that the children who are not yet capable of producing an adult-like /l/ will require more time (duration) to produce consonant clusters in which the other consonant also involves a lingual articulation. We also hypothesize that the intrinsically greater difficulty of producing clusters will result in higher articulatory variability for laterals in clusters than for singletons. The results reported in this paper bear primarily on the first hypothesis.

To test the duration hypothesis, we examined audio recordings and associated lingual ultrasound video (at 60fps) of young English-learning children producing onset singleton laterals (lip, lap) and onset laterals in /kl/- and /sl/- clusters (clip and clap, slip and slap). These children participated in an elicited imitation study in which they were shown an image and heard a recording of the target word produced in isolation, after which they were prompted to repeat the word. Each token was elicited up to 6 different times (in random order). Data from five children, ages 3;0-4;8, have been analyzed to date. These are children whose onset and cluster lateral productions were judged auditorily by adult listeners to be felicitous /l/, /kl/, and /sl/ clusters, with no substitutions (e.g. /t/, /w/ or /j/), deletions, or errors.

Two phonetically trained coders determined the acoustic duration of laterals by examining the audio in Praat (Boersma & Weenik 2015). The onset of /l/ was marked at the beginning of lateral-like characteristics in each word, regardless of whether it occurred during the fricative /s/ or the aspiration of /k/. Lateral offsets were marked at the onset of the following vowel. For laterals produced in clusters, the duration of overlap between the lateral and the preceding consonant was also recorded.

Ultrasound images were gathered from 100ms preceding the onset of the word through 100ms following the offset of the lateral. Two trained coders used Edgetrak (Li et al. 2005) to trace the edges of the tongue. These contours were then plotted to show change over the course of the /l/-, /kl/- and /sl/- articulations. Because probe stabilization was not available for this data, we examined the traces from each production visually, comparing them with the acoustic duration data.

Not surprisingly, we observed a large amount of variation both across and within the five children in their productions of /kl/- and /sl/- clusters. Articulatory variability is a hallmark of young children’s productions (e.g., Fletcher 1989, Smith & Goffman 1998). However, we also found notable consistencies between the children which support our hypothesis. As shown in Figure 1, duration of /l/s in /sl/- clusters were consistently, and significantly, longer than singleton /l/s ($\beta=0.0486$, $r=4.93$), and were generally longer than /l/s in /kl/- clusters ($\beta=0.0030$, $r=0.30$). (A linear mixed effects model was used, with child and word included as random factors. C12 is the only subject whose /l/ productions were equally long in /sl/- and /kl/- clusters.)
The two children with shortest durations for the /l/s in /sl-/ clusters, C08 (mean 137ms) and C11 (mean 136ms), are the same two children who consistently used an adult-like /l/ articulation, with both an anterior and posterior lingual constriction. This is shown for C08 in Figure 2 (left). In contrast, C06, whose /l/ in /sl-/ productions were the longest of the children’s (mean 192ms), is one of three children who produced singleton onset /l/s with a single anterior constriction. (Such children typically use a more advanced tongue position, most likely due to undifferentiation of the lingual articulators (Gibbon 1999).) C06 showed a substantial amount of movement during the auditorily marked /l/ productions, suggesting that the extreme duration of the /l/ may be due in part to this child’s tongue moving between two articulations with extremely distinct positions of the bulk of the tongue body (posterior for /s/ and anterior for /l/), as shown in Figure 2 (right). This greater degree of movement translates, unsurprisingly, into a greater required duration to execute the cluster. In C08’s and C11’s /sl/ productions, while the two consonants are produced distinctly, the more posterior construction of their /l/ productions requires less of the tongue to move, and thus the duration of the lateral is shorter.

![Figure 2](image-url). Representative /l/ and /s/ contours during /sl-/ production for C08 (left) and C06 (right), showing different degrees of movement required. (Anterior facing right.)

While further research with child populations exhibiting a greater range of ages and /l/ lingual postures are required to fully generalize these results, we interpret the alignment of durational and articulatory differences among children in this study as supporting our hypothesis that children who are not yet capable of an adult-like lateral are more likely to lengthen one or more of the consonants in a lingual-lateral consonant cluster. More generally, the results point to the conclusion that children’s productions of consonant clusters requiring gestural coordination depend on covert articulatory details of the individual consonants involved; these details, clearly exposed by ultrasound imaging, vary across individuals, and contribute to the explanation of why children’s phonological patterns are so variable.

References