Liquid coarticulation in child and adult speech

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ABSTRACT

Although liquids are mastered late, English-speaking children are said to have fully acquired these segments by age 8. The aim of this study was to test whether liquid coarticulation was also adult-like by this age. 8-year-old productions of /əLa/ and /əLu/ sequences were compared to 5-year-old and adult productions of these sequences. SSANOVA analyses of formant frequency trajectories indicated that, while adults contrasted rhotics and laterals from the onset of the vocalic sequence, F2 trajectories for rhotics and lateral were overlapped at the onset of the /əLa/ sequence in 8-year-old productions and across the entire /əLu/ sequence. The F2 trajectories for rhotics and laterals were even more overlapped in 5-year olds' productions. Overall, the study suggests that whereas younger children have difficulty coordinating the tongue body/root gesture with the tongue tip gesture, older children still struggle with the intergestural timing associated with liquid production.

Keywords: liquids, speech acquisition, articulatory timing, coarticulation

1. INTRODUCTION

The development of coarticulation requires the acquisition of intergestural timing and coordination of complex segments. Consider, for example, English liquids. Both /ɹ/ and /l/ require the coordination of multiple tongue gestures [9, 13, 19]: laterals require simultaneous tongue body retraction, tongue tip advancement, and lateral airflow [13, 23, 15]; rhotics require tongue root/body retraction, tongue tip advancement, and mid-central airflow [12]. Given this complexity, it is no wonder that English /ɹ/ and /l/ are typically acquired later than other segments [6, 7, 8].

The late acquisition of liquids reflects the complex nature of their articulation, which is often explained as the difficulty inherent in the double articulation of these segment [2, 7]. However, the acquisition problem is more complex than learning articulatory postures for accurate segmental production: to fully acquire liquids and other speech sounds, children must learn to coordinate dynamic articulatory movements; that is, they must learn language-specific coarticulatory patterns. Liquids are especially interesting given this problem because they have particularly strong coarticulatory effects on surrounding vowels [11, 25]. For example, West [26] found a consistent effect of both lowered F3, rounded lips and retracted tongue in /ɹ/ in both anticipatory and preservatory directions. Preceding vowels also had a lower F1 in the rhotic context compared to the lateral context. Tunley [24] found an effect of lowering F2 and F3 preceding vowels up to two-syllables in the rhotic context and increase in F2 and F3 in the lateral context.

As noted, liquid acquisition is protracted, but it is unclear as to whether children are also slow to acquire language-specific coarticulatory patterns. Whereas Sereno, Baum, Marean, & Lieberman [22] found that children showed less labial coarticulation than adults, and that listeners made use of coarticulatory cues to predict upcoming rounded vowels versus unrounded vowels in adults' speech but not in children's speech (see also [14]); others have found that children's speech is more coarticulated than adults' (e.g. [16], [17], and [18]).

The current study investigates the development of anticipatory (co)articulation of liquid segments, with particular attention to the effects on a preceding vowel. We examine 5-year-old and 8-year-old English-speaking children's speech in comparison to adults' speech. Our goal is to better understand the acquisition of liquid contrasts and interarticulatory timing given a complex segmental target. We expected that younger children will have difficulty coordinating the contrastive tongue body/root gestures in both liquids with the tongue tip gesture, in keeping with prior work [2, 25]. Accordingly, we expect a lack of distinction along the F2 formant frequencies and trajectories in rhotics and laterals in 5-year-olds' speech. Given the possibility that coarticulation develops slowly, we also expected that older children would have difficulty producing adult-like coarticulation between the liquids and the surrounding vocalic environment, manifesting as a partial loss of rhotic and lateral contrastiveness.

Our focus on liquids is motivated not only by their articulatory complexity, but also because they can help tease apart the development of V-to-C and V-to-V interactions. Since liquids impose strong coarticulatory effects on surrounding vowels and consonants [11, 25], we predict an interaction between liquids and vowels to emerge as differences in liquid formant patterns as a function of the vowel.

2. METHODS

2.1. Participants

Participants were 8 college-aged adults and 24 school-aged children. Twelve of the children (7 males and 5 females) were 5-years-old (5;2 to 6;2) and 12 (6 males and 6 females) were 8-years-old (7;6 to 8;1). The adult participants were students at the University of Oregon. The children were recruited through YMCA groups and a developmental database maintained at the University of Oregon. All participants completed and passed a hearing test. The adults had no previous self-reported history of speaking disorders. The children had typical speech and language development as assessed by their scores on the Diagnostic Evaluation of Articulation and Phonology (DEAP; Dodd, Zhu, Crosbie, Holm, & Ozanne [5]) and the Clinical Evaluation of Language Fundamentals - Fifth edition (CELF5; Wiig, Semel, & Secord, [27]).

2.2. Stimuli

The target stimuli were composed of the liquids, /r, l/. The target words were *rad*, *rude*, *lad*, and *lewd*, and preceded by /ə/. Tokens containing [æ] and [u] were chosen because they contain a low front vowel and a high back vowel. We anticipate the difference in articulatory gestures will reveal information about the development of coarticulation. The words were produced as an adjective in the carrier phrase "They said it could be the *target* house." Six repetitions of each of the target stimuli were elicited, for a total of 468 tokens (6 words x 6 repetitions x 13 participants = 468 tokens).

2.3. Procedure and Analysis

Data were collected with a Marantz PMD660 digital audio recorder and a Shure ULX wireless microphone. Data were recorded at 44,100 Hz and a 16-bit rate. Participants were prompted with images corresponding to each of the target stimuli and were then participated in the following dialogue: "Look at this house, I think it could be *the* ____ house. What kind of house did I say it could be?" Participants would respond: "They said it could be *the* ____ house." Participants would be prompted again: "What kind of house did they say it could be?" Participants responded again: "They said it could be *the* ____ house." Thus, two repetitions of the target /əLa/ or /əLu/ sequence were acquired with each picture prompt. The experimenter went through the pictures with the speaker 3 times in random order.

Acoustic measures were taken in Praat [1] for F1 to F3. Measures were taken at 10 temporal points from the onset of the schwa in "the" to the offset of the liquid. The offset of the liquid was determined by an increase in F2 following the dip in F2 associated with the liquid articulation. Formant comparisons were done within each age group (5, 8, 20+) to examine the difference in formant trajectories between the liquids with smoothing spline (SS)ANOVA. SSANOVA plots a best fit contour with 95% confidence intervals and can be interpreted as statistically significant when the boundaries do not overlap [4, 10]. The liquids were then compared in each of the two contrasting phonetic environments.

3. RESULTS

First, the results for the adult speakers are presented in order to show target formant trajectories for the liquids. Second, the results for the 8-year-olds are presented, followed finally by the 5-year-olds. All plots present the formant frequencies and trajectories for /əL/.

3.1. Adults' Speech

Figure 1 presents the dynamic formant frequencies for the *rad* and *lad* comparisons for adults who show a clear distinction between F2 for laterals and rhotics over the duration of articulation. F2 is consistently lower for the lateral than the rhotic. F3 is also clearly separated through the schwa and into the liquid. F3 exhibits a sharp drop for rhotics, while it slightly increases for laterals.

Figure 1: Adults' F1, F2, and F3 trajectories in /əL/ for *the rad house* and *the lad house*.

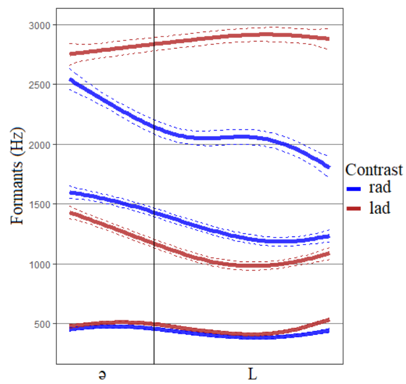
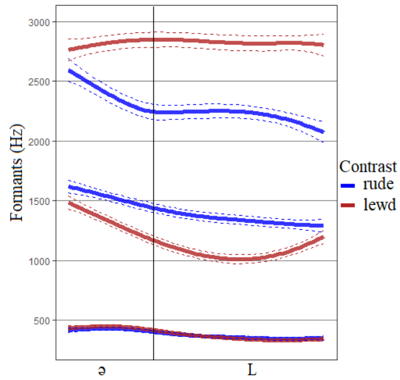


Figure 2 presents the dynamic formant frequencies for the *rude* and *lewd* comparisons for adults. As with the *rad* and *lad* comparisons, there is a clear distinction in F2 between liquids, but the smaller separation between these formants at schwa onset becomes larger over the duration of articulation and then narrows again. F3 also drops, but not as sharply as in the *rad* and *lad* comparisons.

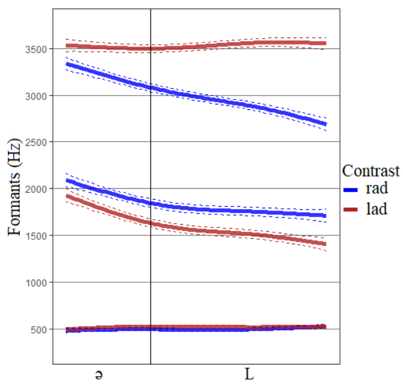
Figure 2: Adults' F1, F2, and F3 trajectories in /əL/ for *the rude house* and *the lewd house targets.*



3.2. Older Children's Speech

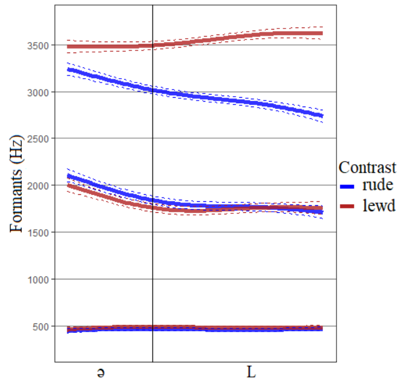
Figure 3 shows the results for *rad* and *lad* in older children's speech, which is like the results from adult speech in that there is a difference in F2 that emerges during liquid articulation, albeit later than in adult speech. Like adults, 8-year-olds also produce a sharp F3 contrast, which presents itself as a drop in F3 of approximately 800 Hz for the rhotic. F3 for the lateral remains relatively stable over the duration of articulation.

Figure 3: 8-year-olds' F1, F2, and F3 trajectories in /əL/ for *the rad house* and the *lad house.*



The formant comparisons for the 8-year olds articulation of the *rude* and *lewd* revealed that there was no significant difference between the formant frequencies for F2 of the liquids. F3 for the rhotic drops approximately 700 Hz. The reason for the difference in drop in F3 between *rad* and *rude* is a lower F3 at the onset of the schwa. This is likely due to vowel-to-vowel coarticulation associated with lip rounding. Figure 4 presents the dynamic formant frequencies for the *rude* and *lewd* comparison for 8-year olds.

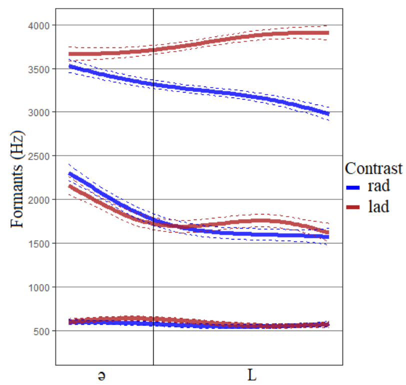
Figure 4: 8-year-olds' F1, F2, and F3 trajectories in /əL/ for *the rude house* and *the lewd house targets.*



3.2. Younger Children's Speech

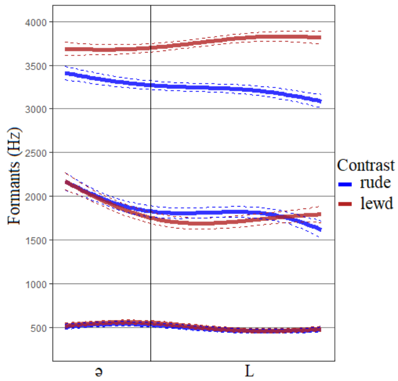
Unlike the adults or older children, younger children's *rad* and *lad* revealed no significant difference in the formant frequencies or trajectories for F2. Like the adults and older children, younger children's F3 drops approximately 1,000 Hz from the onset of the schwa to the offset of the rhotic. The lateral has an increase of approximately 200 Hz from the onset of the schwa to the offset of the lateral. Figure 5 presents the dynamic formant frequencies for the *rad* and *lad* comparison for the 5-year-olds' speech.

Figure 5: 5-year-olds' F1, F2, and F3 trajectories in /əL/ for *the rad house* and the *lad house.*



The comparison of the *rude* and *lewd* contrasts in the 5-year-olds' speech once again revealed no significant difference between the formant frequencies and trajectories for F2. For the rhotic, F3 drops approximately 800 Hz over the articulation of the schwa and liquid. F3 for the lateral remains relatively stable. Figure 6 presents the SSANOVA results for the 5-year-olds' articulation of rude and lewd.

Figure 6: 5-year-olds' F1, F2, and F3 trajectories in /əL/ for *the rude house* and *the lewd house targets.*



4. DISCUSSION

In this study, we presented an acoustic analysis of adults' speech compared to 5- and 8-year-olds' speech. The results revealed an F2 contrast between laterals and rhotics in adult speech from the onset of a preceding schwa through liquid articulation. There was also a distinction in F3 frequencies for the rhotic and the lateral: the rhotic had a falling F3, while the lateral did not. Unlike adults, 5-year-olds did not contrast laterals and rhotics along the F2 dimension. 8-year olds used F2 to contrast rhotics and laterals in the /əLa/ sequence but not in the /əLu/ sequence. Both 5- and 8-year-olds contrasted rhotics and laterals along the F3 dimension no matter the segmental context.

The results from 5-year-olds' speech suggests that although young children can reliably contrast laterals and rhotics using F3, they have not yet mastered the articulatory gestures need to produce the F2 contrasts between the two segments. This is likely due to difficulty in coordinating anatomically coupled articulators, the tongue body and the tongue tip. Fine motor control is necessary to coordinate (near) simultaneous retraction and advancement of the tongue [9, 19] and even though 5-year-olds can approximate liquid articulation, they still have not developed the motor control necessary to make fine distinctions in place of articulation. This results in the lack of F2 contrasts between the two liquids. The consistent contrast in F3 suggests that children do not have difficulty in coordinating multiple articulators when they are anatomically independent of each other.

The difficulty children seem to have with fully coordinating the anterior and posterior portions of the tongue simultaneously might offer a reason why liquids are both acquired late [6, 8] and why certain glide and consonant substitution are so common [3, 20]. The substitutions that typically occur reflects the loss of one of the tongue gestures associated with liquid articulation. If the posterior gesture is completely lost, a lateral may be realized as a stop and when the anterior gesture is lost, a glide is likely to be realized. The common substitution of a rhotic for a glide is also readily explained by the loss of the tongue tip gesture [8].

In contrast, the results from 8-year-olds' speech revealed the extent to which the development of language specific coarticulatory patterns take time to master: 8-year-olds' productions were context dependent. This result is in line with Rubertus & Noiray's [21] assertion that children develop language specific coarticulatory patterns much later than phonemic contrasts in the language. The results revealed that while 8-year-olds may have acquired the tongue gestures involved in different contrasts, they have not yet mastered intergestural timing. Children must also learn the motor patterns associated with different gestural overlap. In the case of /əLa/, 8-year-olds likely mis-time the amount of overlap between the schwa and rhotic, causing excessive anticipatory F2 lowering. In the case of /əLu/, the interaction between the gestures for /u/ and the liquid caused more retraction for the rhotic, leading lower F2. Incomplete acquisition of the proper timing of gestures between segments results in non-native-like coarticulation due to improper sequencing of the activation of the tongue tip and body gestures involved in liquids and vowels.

The results also shed light on the nature of V-to-C interactions. The difference between in F2 across age groups for the liquids is best explained as difficulty implementing V-to-C interactions. Coordinating the tongue body gesture for both the vowel and liquid takes time to master. Liquids have extensive coarticulatory resistance and effects on neighbouring segments [11, 25] and children have to develop the motor control to execute those interactions.

5. CONCLUSIONS

In order to produce native-like speech, children must master articulatory postures to achieve phonemic contrasts in a language. They must also master sequential articulatory timing relations that are specific to the language being acquired. The results from the current study suggest that it takes longer to master sequential timing than the interarticulatory coordination necessary to achieve segmental targets.the sequential aspects.

5. ACKNOWLEDGEMENTS

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