//l// in clusters: an articulatory-acoustic study of children’s productions

Susan Lin, Sharon Inkelas, Lara McConnaughey, Michael Dohn
English /l/ production

• Adult speakers of several varieties of English typically produce both onset and coda /l/ with both an an anterior and a posterior constriction (e.g., Giles & Moll, 1973, Gick, Wilson, & Derrick, 2013, Huffman, 1997)
Complex consonant acquisition

- Consonants (and consonant sequences) requiring the coordination of multiple lingual articulators are typically acquired late by children (e.g., Goad & Rose 2004, Gerlach 2010)
  - Acquired late: liquids (/l/, /ɾ/), affricates (/tʃ/, /dʒ/)
  - Acquired early: nasals (/m/, /n/), glide (/w/)

- Children’s tongues do not assume adult-like proportions and control until age 5;6, on average (e.g., Denny and McGowan, 2012)
Background: Lin & Demuth 2015

• 25 children acquiring Australian English
  – Ages 3;1-7;11
  – Word repetition task; monosyllabic words containing singleton /l/
  – Ultrasound images and audio collected

• Audio coded for auditory “accuracy”

• Ultrasound coded for presence of anterior and/or posterior tongue constriction
Background: child English onset /l/

double-constriction (adult-like)
single-constriction (anterior)
/l-/ type usage is age graded

- In words coded by transcribers as having auditorily accurate /l/,
  - 60% of 3-year-olds and 40% of older children exhibited only a single anterior constriction
  - The remainder had both anterior and posterior constrictions
This study

• Young children can produce auditorily acceptable onset /l/ as early as 3;0; but articulation may be distinct from adults’

• This study: production of /kl-/ and /sl-/ onset clusters by children
  – What is the effect of /l/ on onset cluster production?
  – Focus on /sl-/ and /kl-/ clusters
/k-/ , /s-/ , and /l-/ articulations

adult

posterior  k  posterior  l  s

child (not adult-like)

posterior  k  anterior  l  anterior  s
Hypotheses

Children whose /l/-/ productions are articulatorily less adult-like may produce /kl/- and /sl/- clusters (relative to singleton /l/-/ productions) distinctly from adults

- H1 (durational): children’s /Cl/-/ durations will become more adult-like with age
- H2 (temporo-gestural): this will be correlated with differences in the use of /l/ articulation type
Study design

• 19 English-learning children (3;0-7;11) and 5 adult native English speakers
  – Data from Lin & Demuth (2015)

• Acoustic recordings and lingual ultrasound video of /l-/, /kl-/, and /sl-/ words

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
Study design

• Word reading / elicited imitation
  – Monosyllabic words with vowels /ɪ/ and /æ/
  – Words produced in isolation

<table>
<thead>
<tr>
<th>l-onset</th>
<th>kl-onset</th>
<th>sl-onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>lip</td>
<td>clip</td>
<td>slip</td>
</tr>
<tr>
<td>lap</td>
<td>clap</td>
<td>slap</td>
</tr>
</tbody>
</table>
Analysis: durational

- Acoustic landmarks annotated in Praat
  - Acoustic onset and release of /k/, /s/
  - Acoustic onset and release of perceptible /l/
Ultrasound visualization

- Tongue contours in ultrasound images traced using EdgeTrak (Li et al. 2005)
Results: /l/ duration

/l/ duration, by context and age

N = 1
Results: /l/ duration by subject

/l/ duration, by context and subject

/adults/
Results: durational

• H1 (durational): children’s segmental durations will become more adult-like with age ✓

• But lots of variability between children
  – Is this variability due to differences in use of /l/-articulation type?

• H2 (temporo-gestural): variation will be correlated with differences in the use of /l/ articulation type
Ultrasound: visual inspection

- **C08**: short /l/ in /sl-/ clusters (mean 137 ms)
  - Articulations very similar

- **C06**: long /l/ in /sl-/ clusters (mean 192 ms)
  - Articulations farther apart
Digging deeper: acoustics

• H2 (temporo-gestural): variation in duration will be correlated with differences in the use of /l/ articulation type

• A child producing anterior-only lateral productions
  – will require more time than anterior-posterior productions to transition from /k/ articulation
  – will require less time than anterior-posterior productions to transition from /s/ articulation
Analysis: acoustic

• F1-F2 distance as a metric of acoustic “darkness”, and a stand-in for velarization
  – Close F1 and F2 $\rightarrow$ greater velarization
    (Sproat and Fujimura, 1993; Recasens and Espinosa 2005)

• Mean F1 and F2 during acoustic /l/
  – Measurements every 5ms
  – Converted to Bark
    (Traunmüller, 1990)
H2 (acoustic version)

- F2-F1 of laterals should be correlated with duration
  - Positively in /kl-/
  - Negatively in /sl-/

Duration

F2-F1
Results: Acoustic

- F2-F1 of laterals should be correlated with duration
  - Positively in /kl-/ clusters \( (p=0.0530) \)
  - Negatively in /sl-/ clusters \( (p=0.0027) \)

Linear mixed effects models
- Random factors: subject, vowel
Summary

• Children’s productions of /l/ in /kl-/ and /sl-/ clusters differ from adults’ in relative duration

• Differences are age-related – older children more likely to exhibit adult-like behavior – but also appear to be linked to differences in articulation
Caveats

• No analysis of relative timings
• No singleton /k-/ or /s-/ comparison!
• No /pl-/ comparison!
• Limited vowel context!
Future Questions / Directions

We have focused here on /l/-type as a predicting variable.

• In children’s clusters, which consonant is most affected in its articulation by the contribution of the other consonant?

Some children use multiple types of onset /l/s

• How much control do they have over when to use which one?

• Does such control extend to multilingual adult speakers whose languages utilize distinct /l/ articulations?
Selected references


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  – Ronald Sprouse and Matthew Faytak
• Audience Members at ICPC for helpful suggestions and insights
Thank you!
F2–F1, by age and preceding context

![Graph showing F2–F1 by age and preceding context](image)

- **Y-axis:** F2–F1 (Bark)
- **X-axis:** Age (years)
- **Legend:**
  - k
  - s
/l/ duration, by context and age
Consonantal overlap, by participant and C1
Table 4. The six articulatory combinations possible for the three constrictions (anterior, posterior, labial) and percentage of each combination produced by child participants rated as accurate productions of target segments.

| Adult-like | Constrictions Target segments (%)
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>/l/</td>
<td>Yes</td>
</tr>
<tr>
<td>/w/</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>33</td>
</tr>
</tbody>
</table>

Note. Combinations appearing fewer than five times were not included in this table. Articulatorily adultlike productions are denoted in the left-most column. Dashes indicate data not reported.