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

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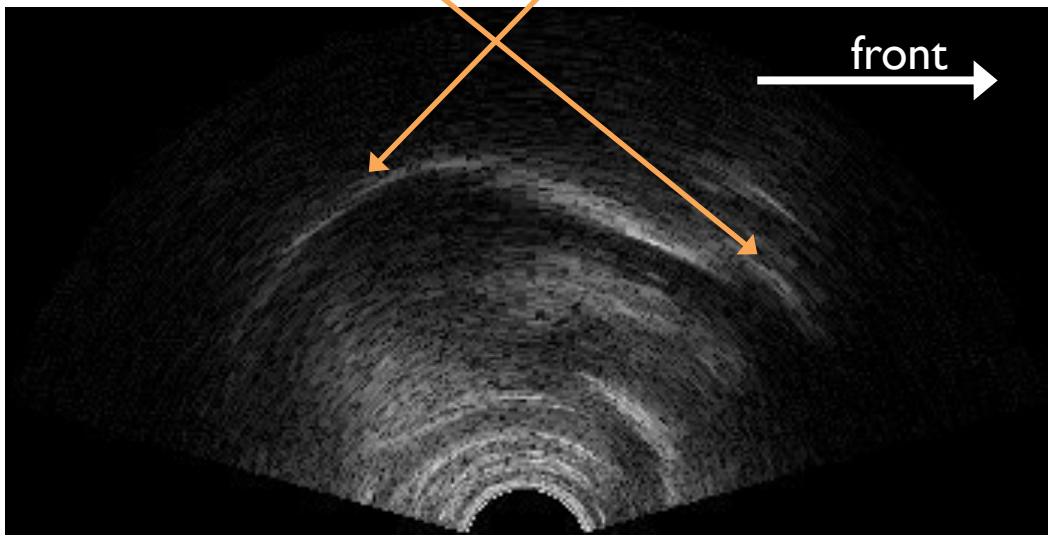
English /l/ production

- 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

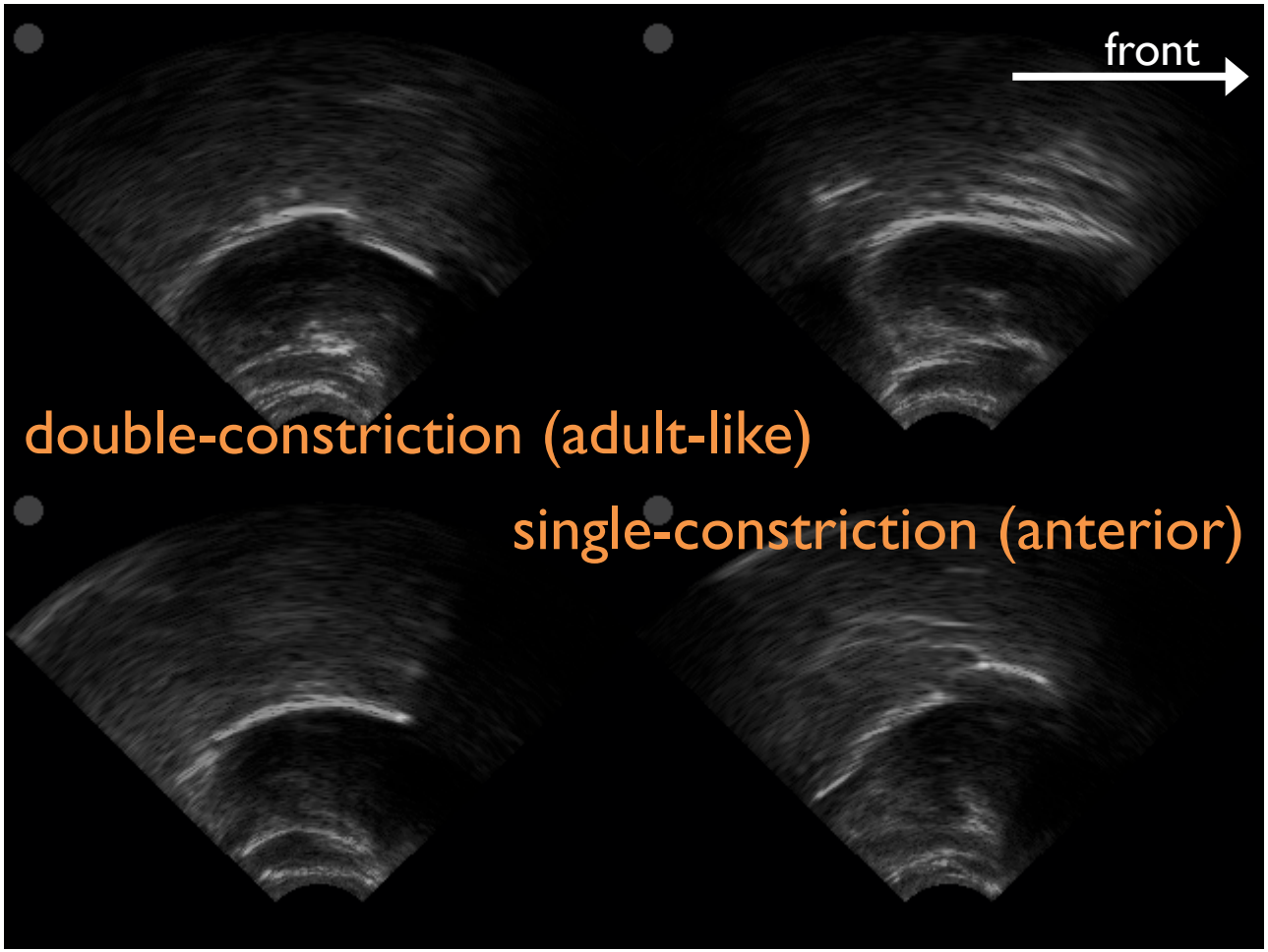
  (e.g., Goad & Rose 2004, Gerlach 2010)

  - Acquired late: liquids (/l/, /ɹ/), 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

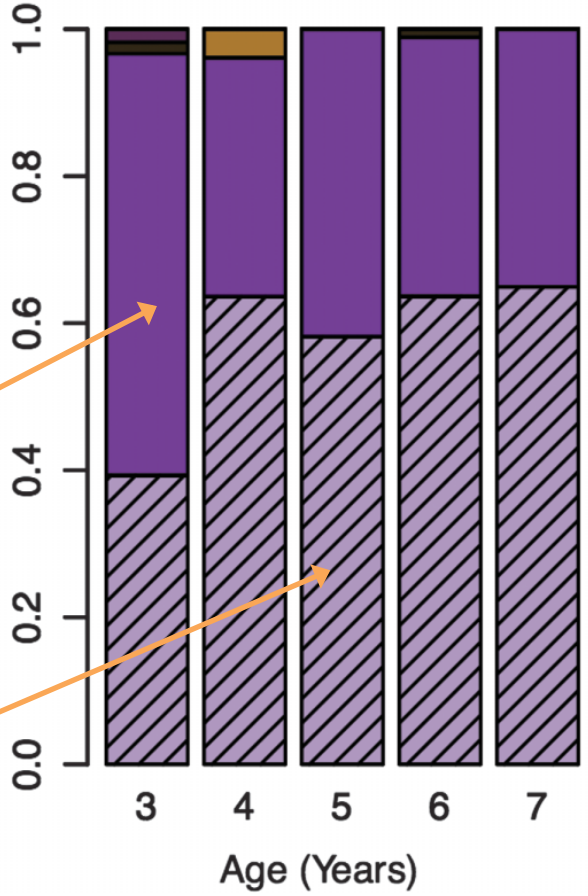
- 25 children acquiring Australian English
  - Ages 3;1-7;11
  - Word repetition task; monosyllabic words containing singleton /l/
  - Ultrasound images and audio collected
- Audio coded for auditory "accuracy"
- Ultrasound coded for presence of anterior and/or posterior tongue constriction

Background: child English onset /l/



/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

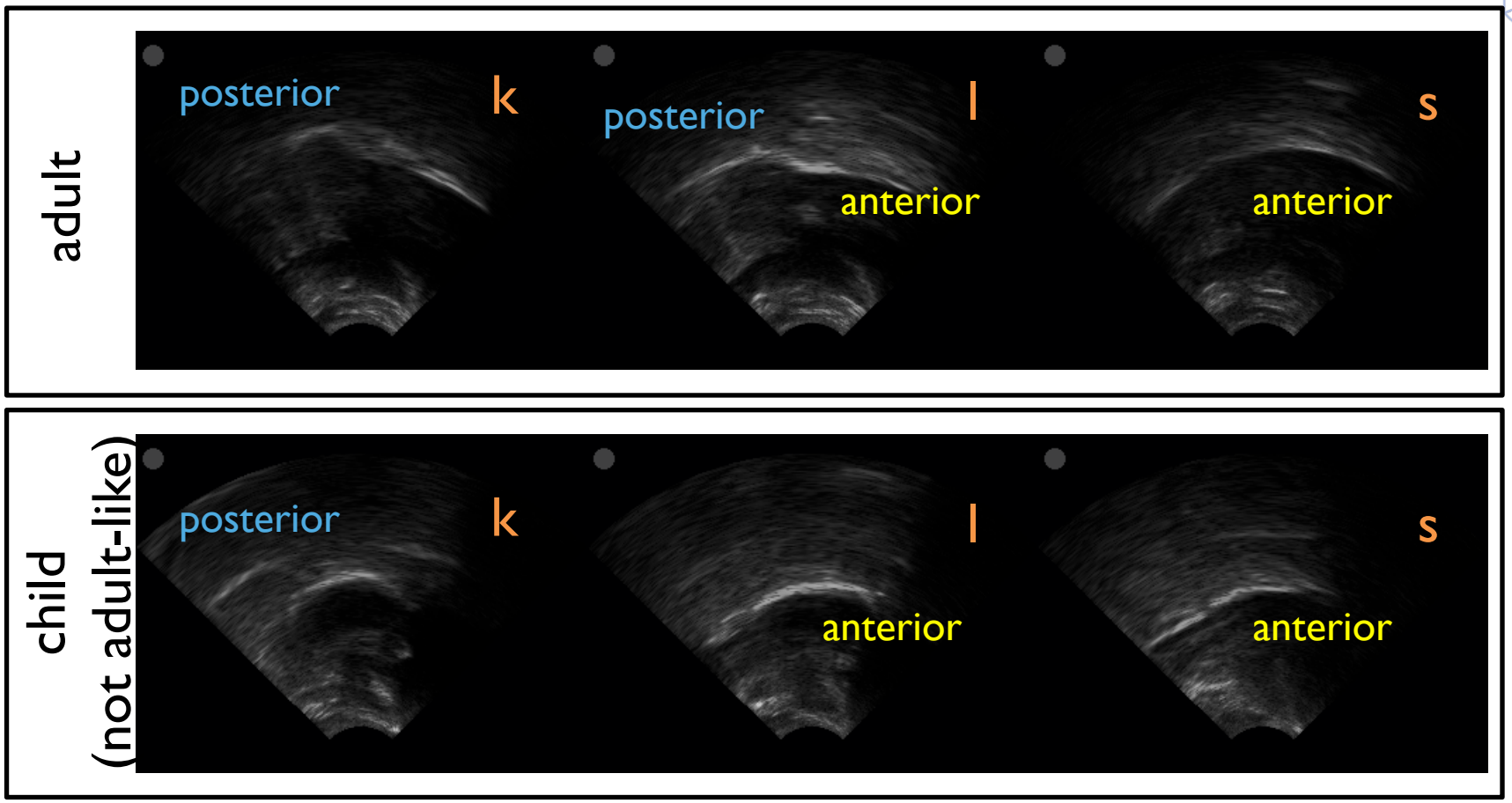


This study

- 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



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

Age (years)	3	4	5	6	7	adult
N=	5	4	4	1	5	5

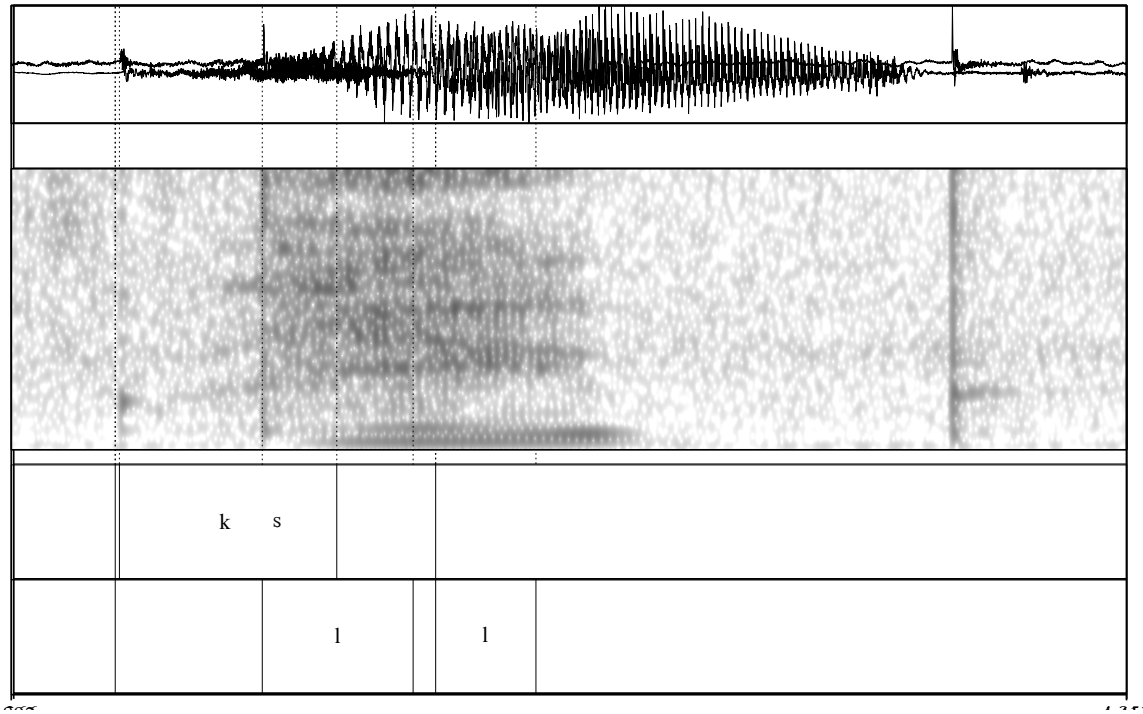
Study design

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

l-onset	kl-onset	sl-onset
lip	*clip*	*slip*
lap	*clap*	*slap*

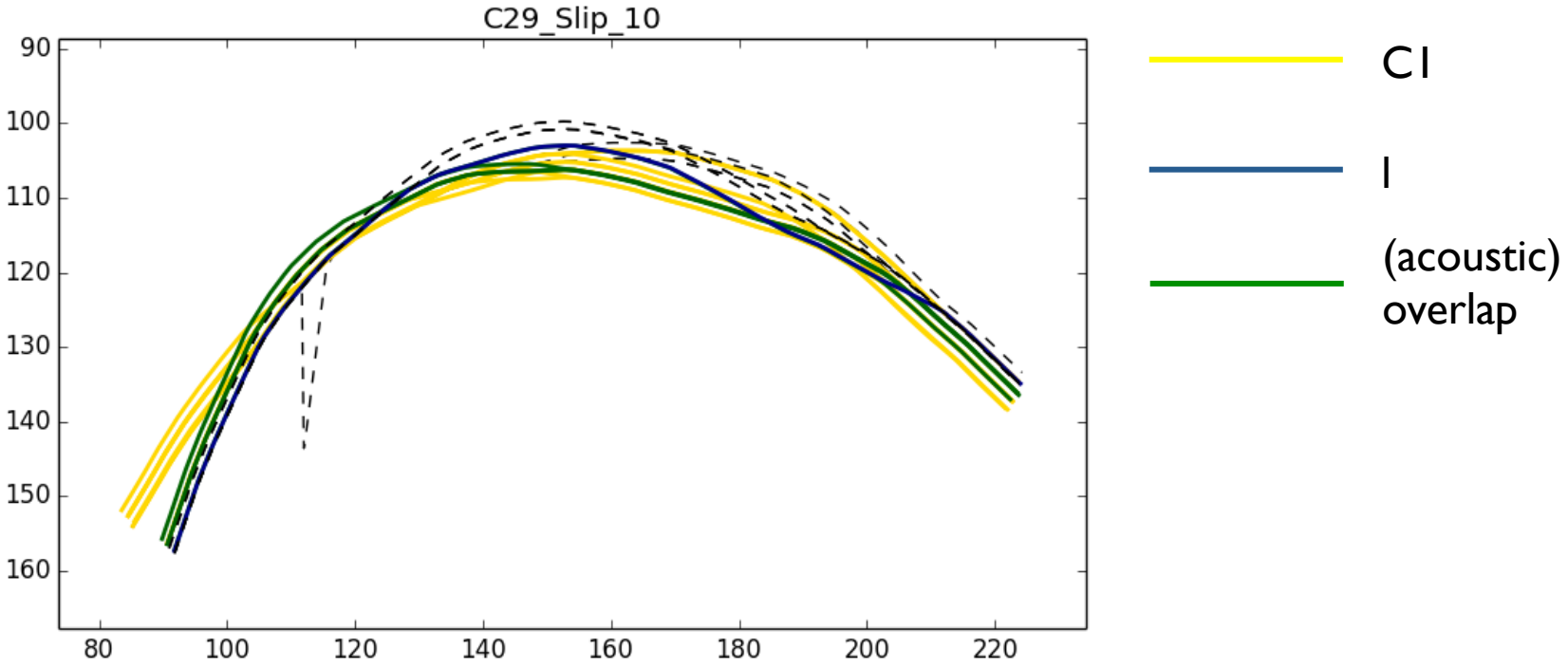
Analysis: durational

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

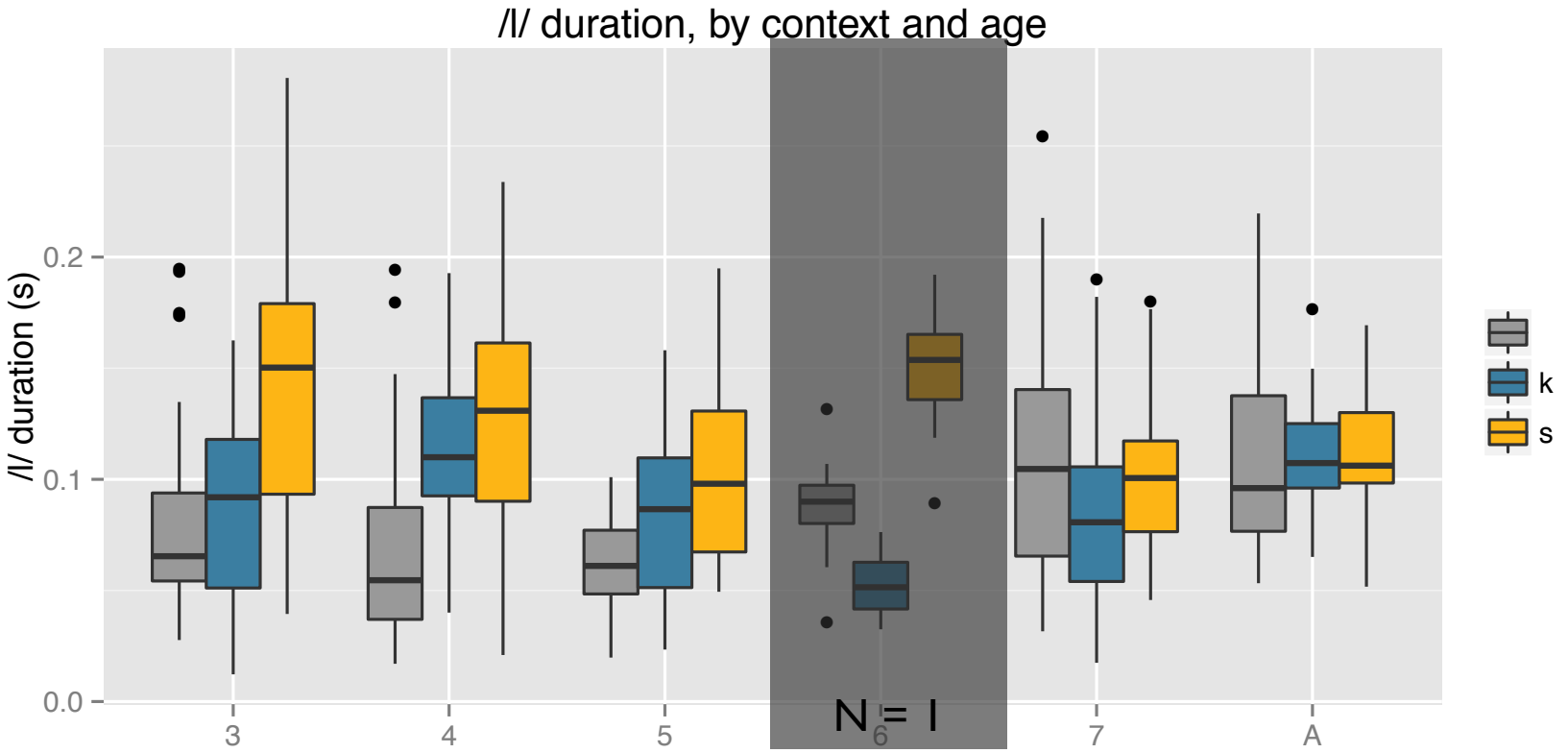


Ultrasound visualization

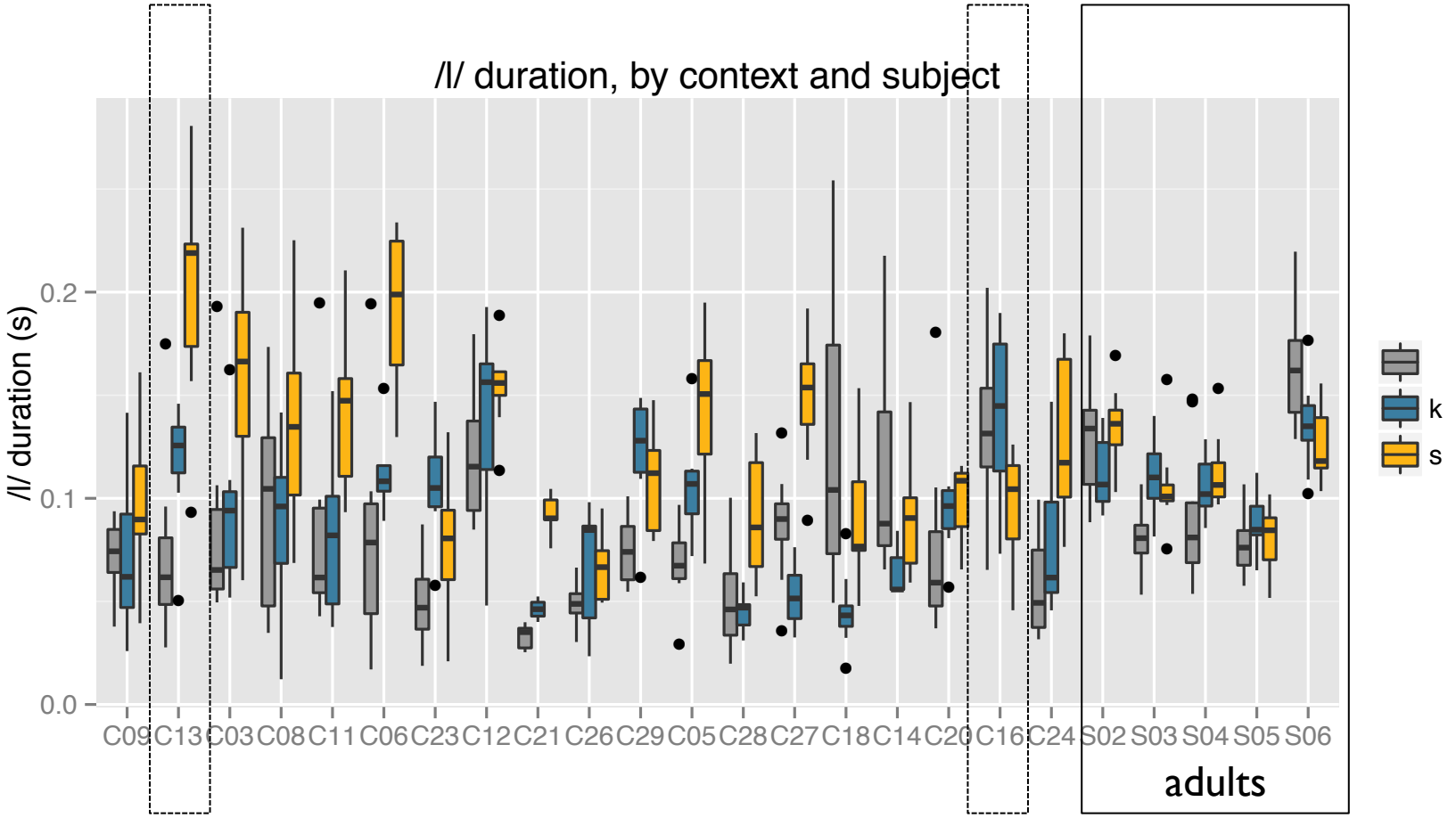
- Tongue contours in ultrasound images traced using EdgeTrak (Li et al. 2005)



Results: /l/ duration



Results: /l/ duration by subject



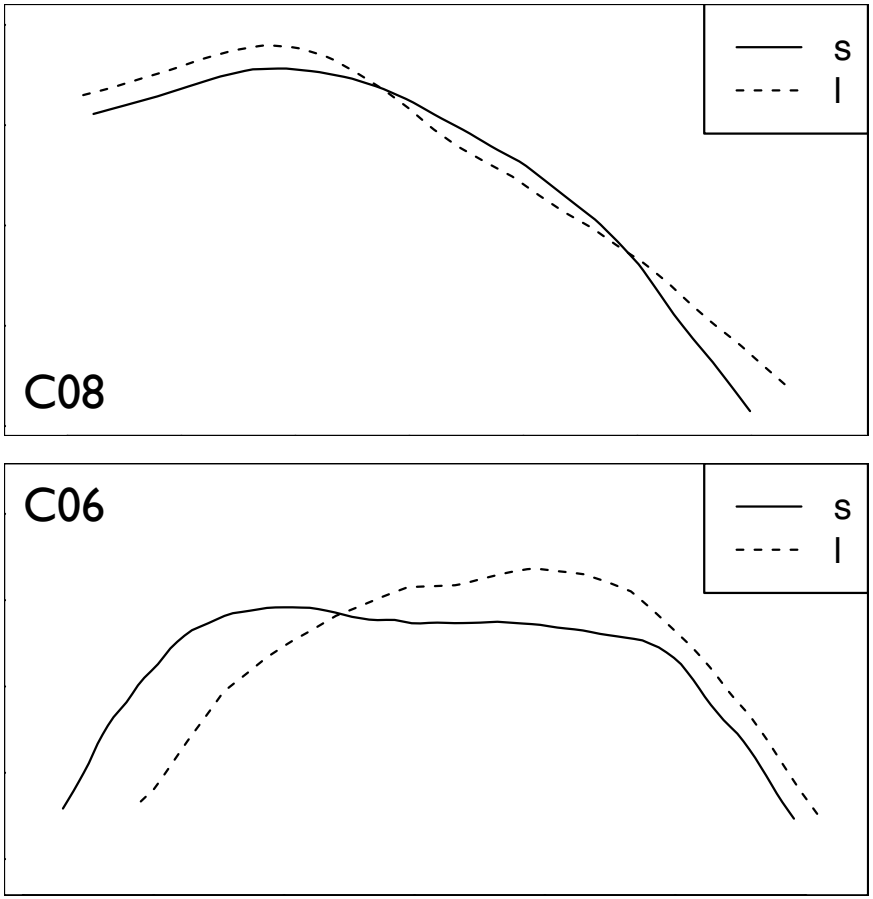
Results: durational

- 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 → greater velarization

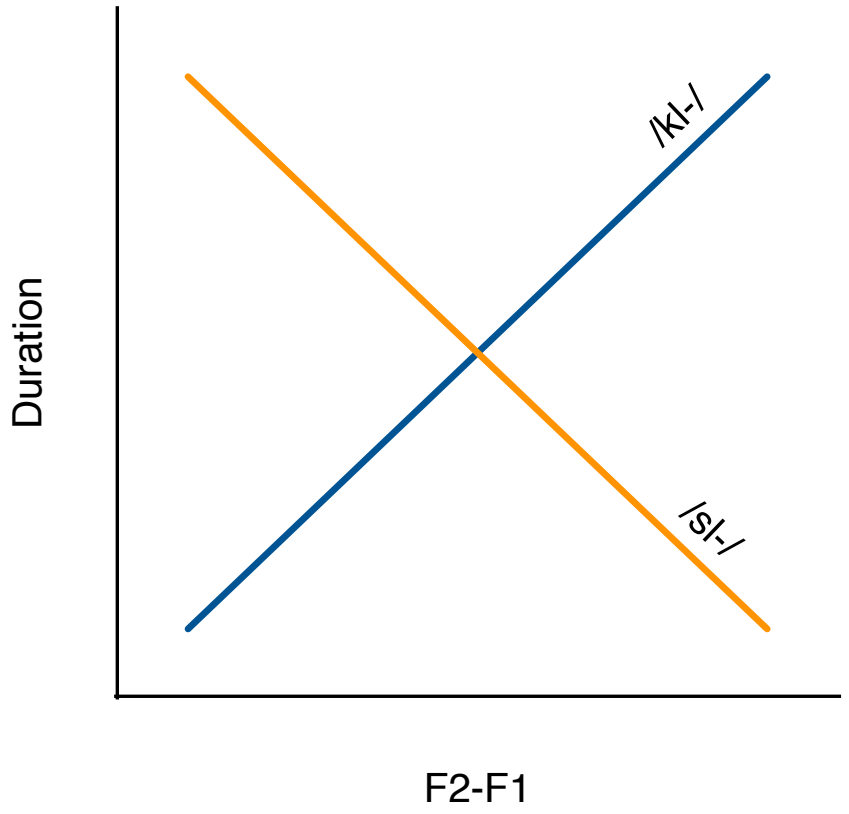
(Sproat and Fujimura, 1993; Recasens and Espinosa 2005)

- Mean F1 and F2 during acoustic /l/
  - Measurements every 5ms
  - Converted to Bark

(Traunmüller, 1990)

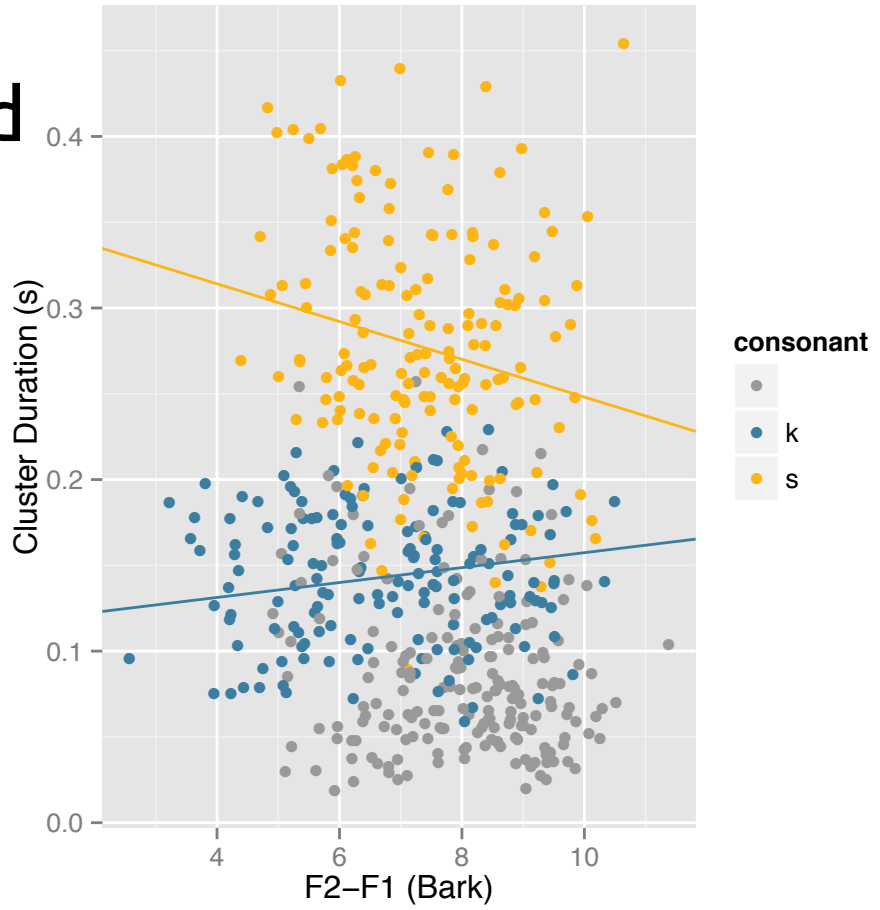
H2 (acoustic version)

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



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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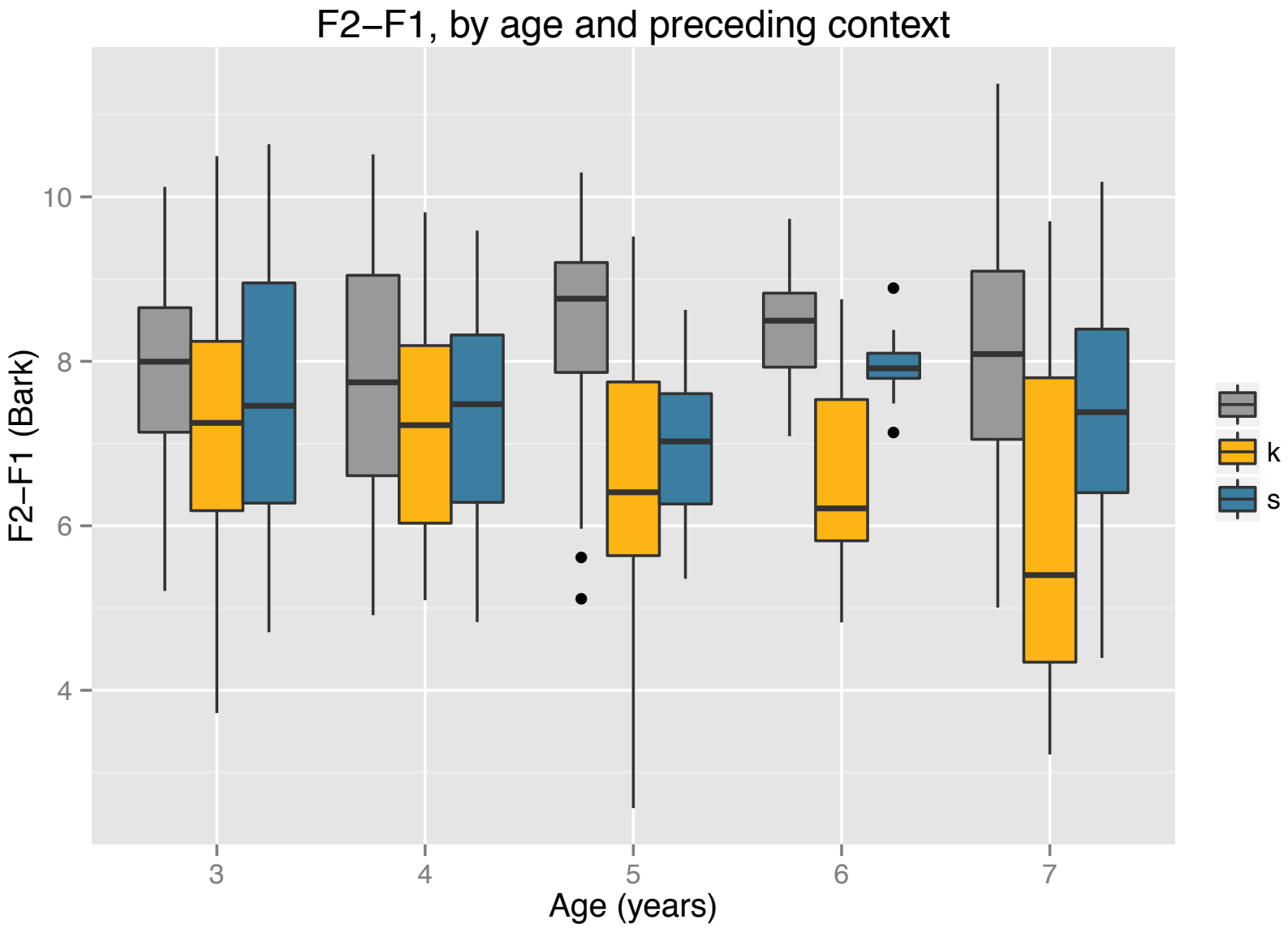
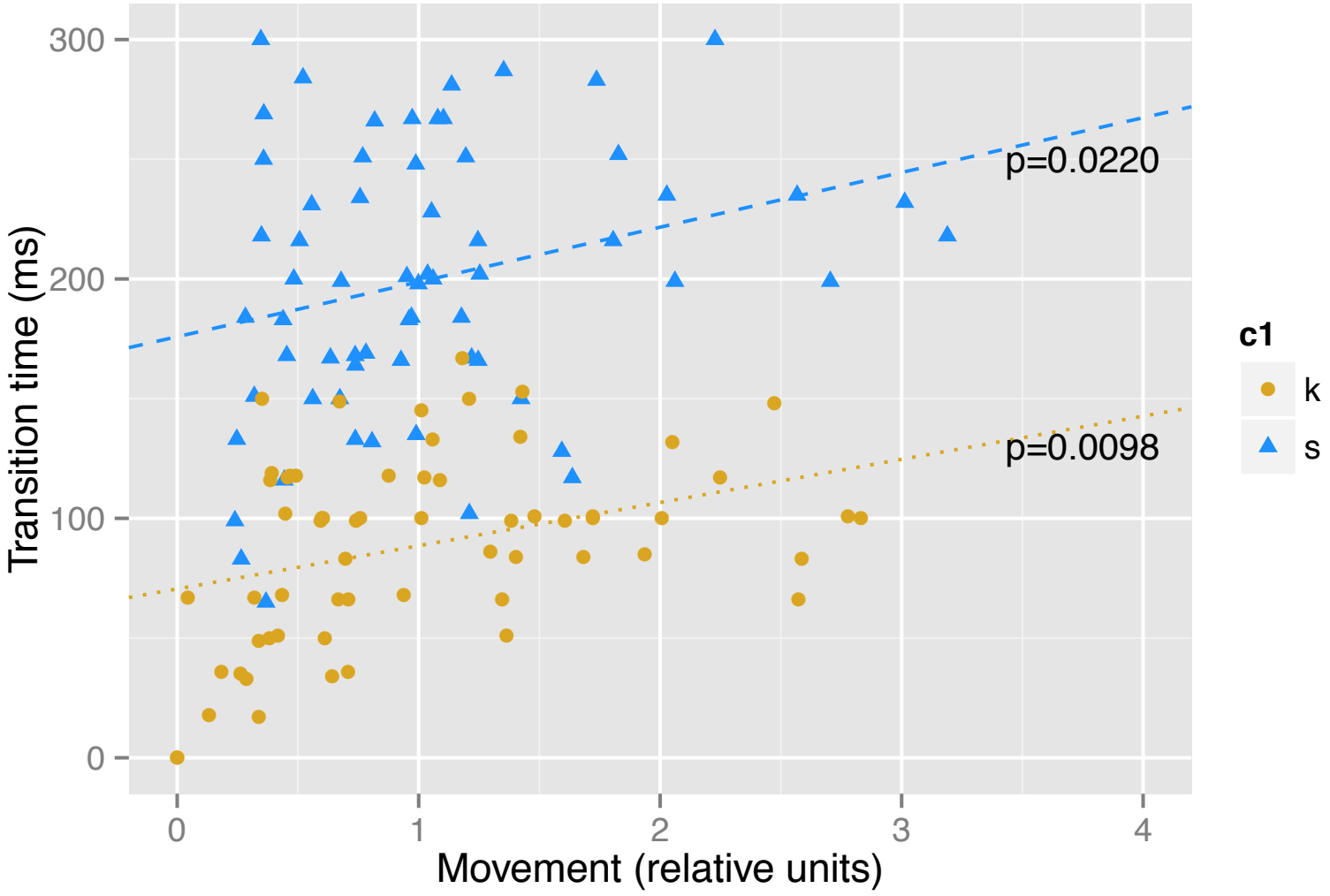
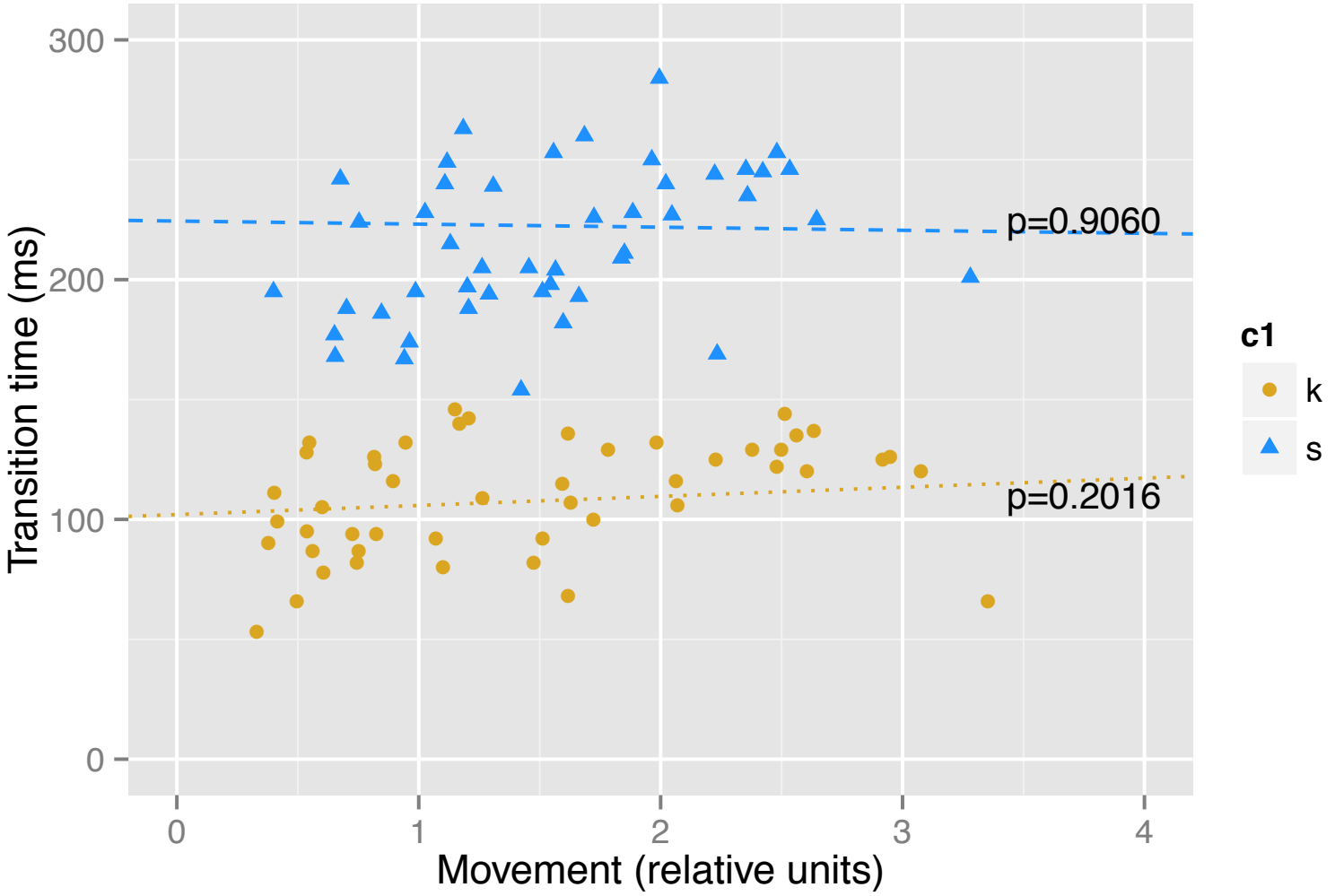
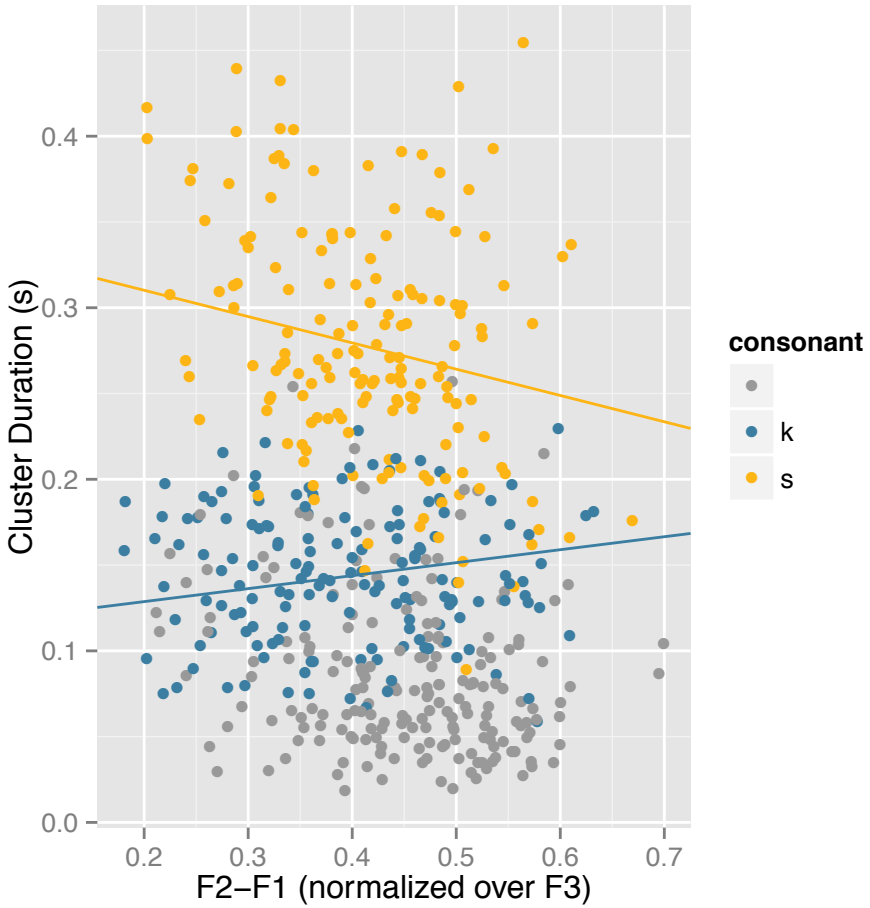
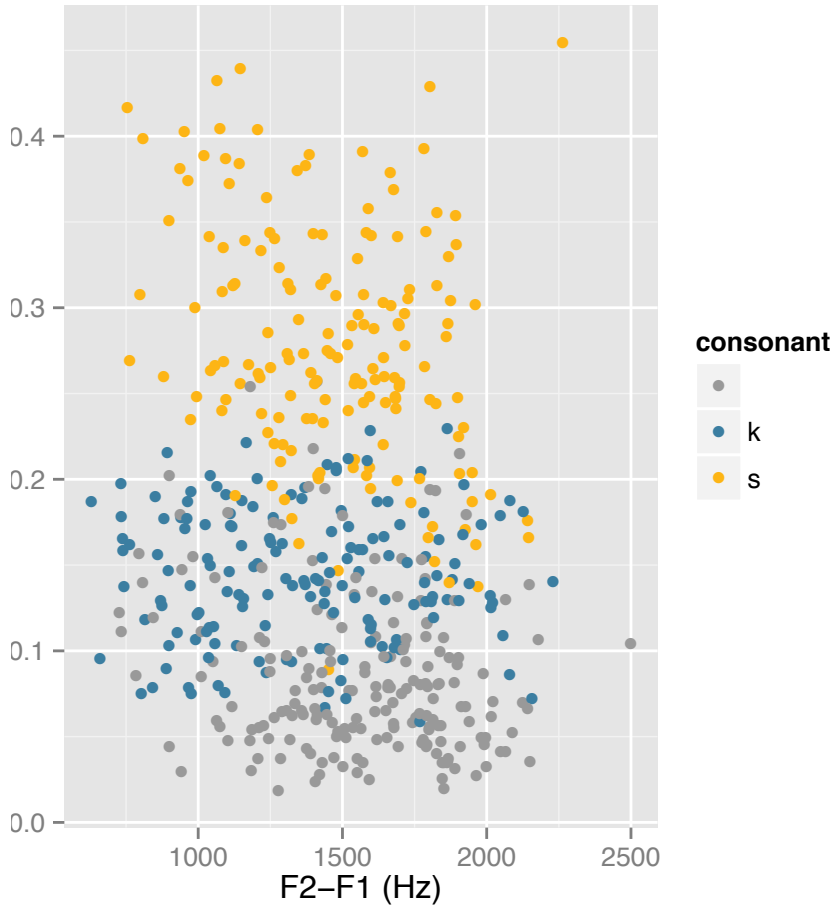
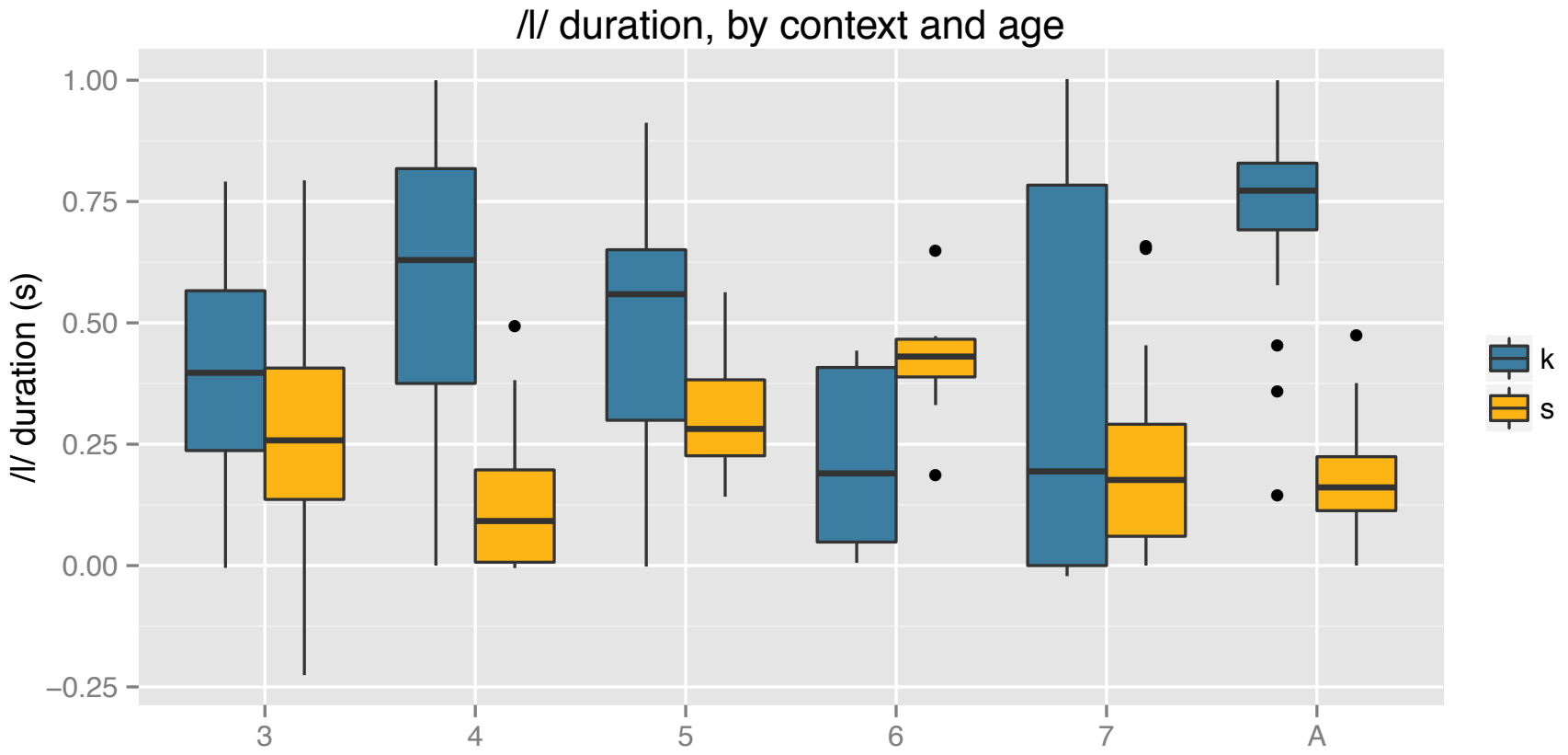

F2–F1, by age and preceding context
F2–F1 (Bark)
10
8
6
4
3
4
5
6
7
Age (years)
k
s

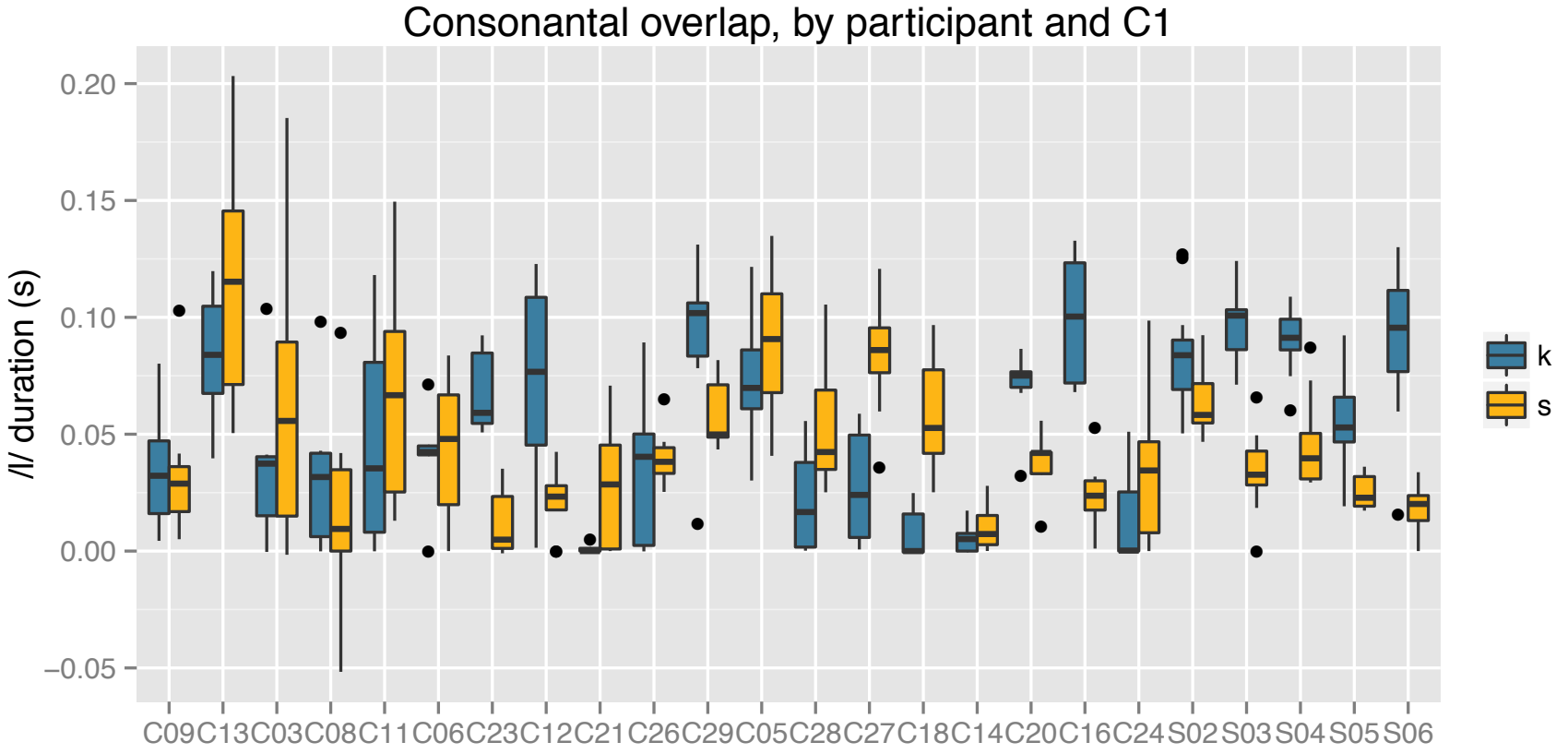

300
200
100
0
Transition time (ms)
0
1
2
3
4
Movement (relative units)
p=0.0220
p=0.0098
c1
k
s

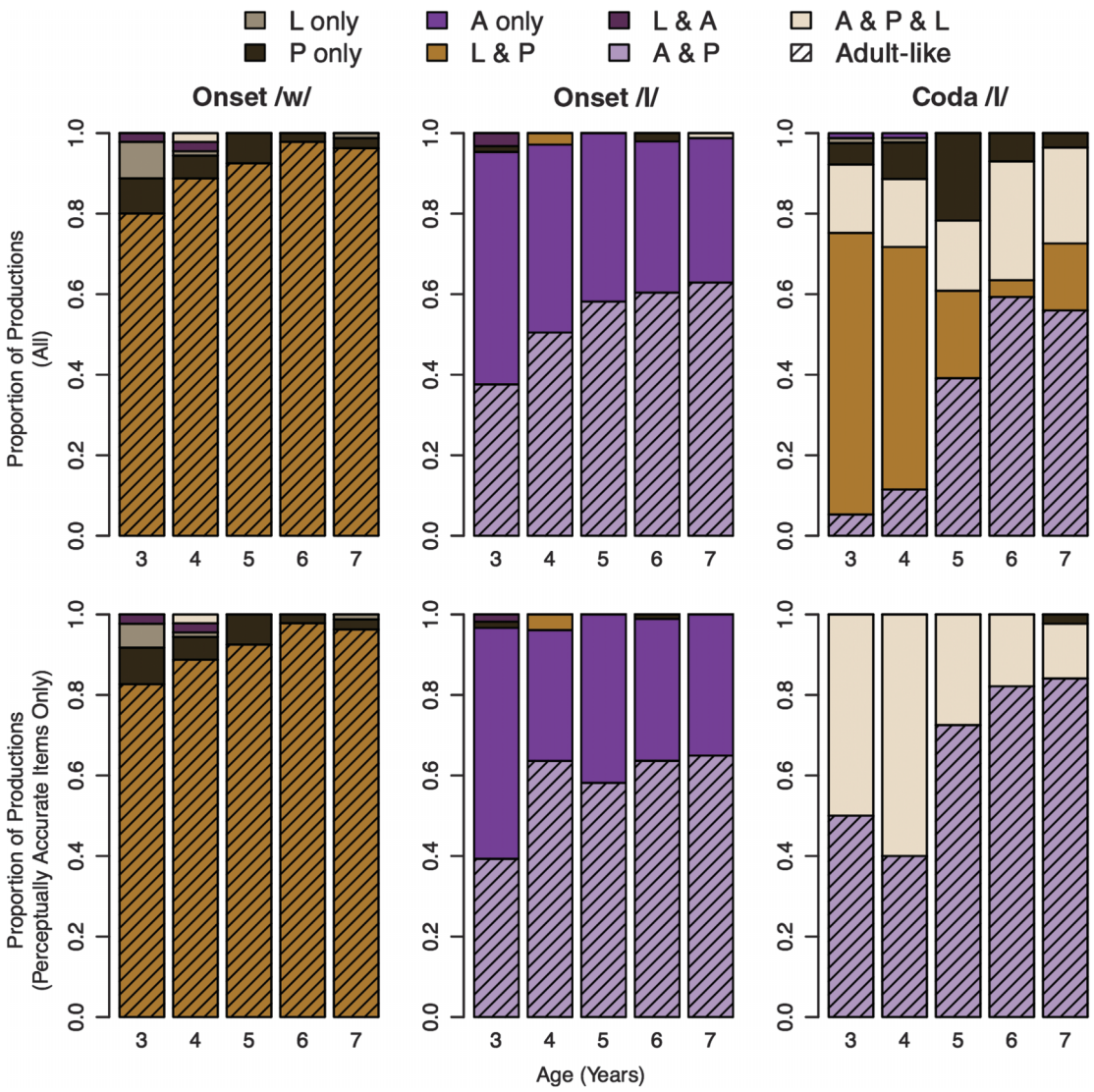

300
200
100
0
Transition time (ms)
0
1
2
3
4
Movement (relative units)
p=0.9060
p=0.2016
c1
k
s


Cluster Duration (s)
0.0
0.1
0.2
0.3
0.4
0.2
0.3
0.4
0.5
0.6
0.7
F2–F1 (normalized over F3)
consonant
k
s


0.0
0.1
0.2
0.3
0.4
1000
1500
2000
2500
F2–F1 (Hz)
consonant
k
s


/l/ duration, by context and age
/l/ duration (s)
1.00
0.75
0.50
0.25
0.00
−0.25
3
4
5
6
7
A
k
s


Consonantal overlap, by participant and C1
/l/ duration (s)
0.20
0.15
0.10
0.05
0.00
−0.05
C09 C13 C03 C08 C11 C06 C23 C12 C21 C26 C29 C05 C28 C27 C18 C14 C20 C16 C24 S02 S03 S04 S05 S06
k
s


L only
P only
A only
L & P
L & A
A & P
A & P & L
Adult-like
Onset /w/
Onset /l/
Coda /l/
Proportion of Productions (All)
Proportion of Productions (Perceptually Accurate Items Only)
0.0
0.2
0.4
0.6
0.8
1.0
3
4
5
6
7
Age (Years)