A motor differentiation model for liquid substitutions: English /r/ variants in normal and disordered acquisition

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Goals

1. To describe a model in which children's developing speech motor systems strive to reduce the degrees of freedom of complex anatomical structures (e.g., the tongue).

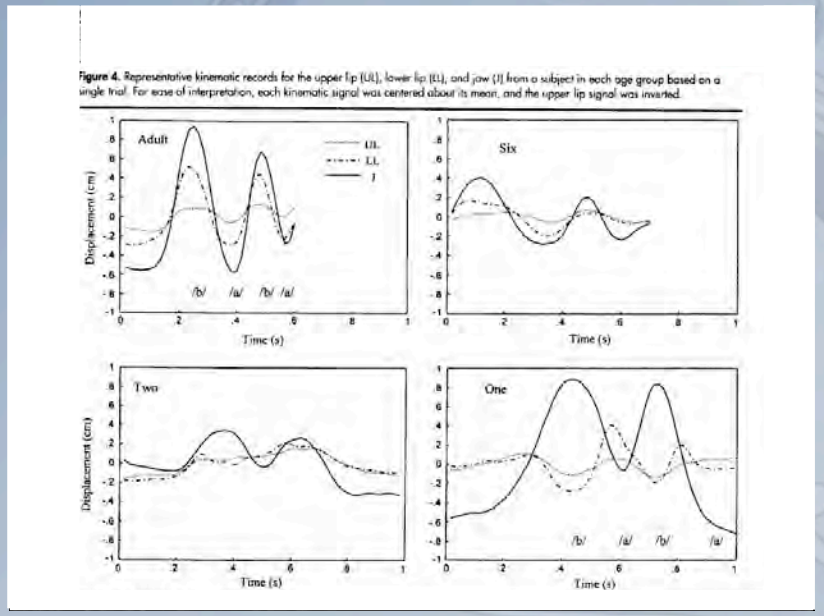
2. To show that common segmental substitutions (e.g., [w] for /r/ or /l/) can be described as being the result of specific strategies that aim to simplify lingual degrees of freedom.

Background

Infants simplify arm reaching tasks by locking joints (Berthier & Keen 2006), thereby reducing kinematic degrees of freedom.

Similar simplification can be seen in lip-jaw coordination in children's speech (Green & al. 2000):

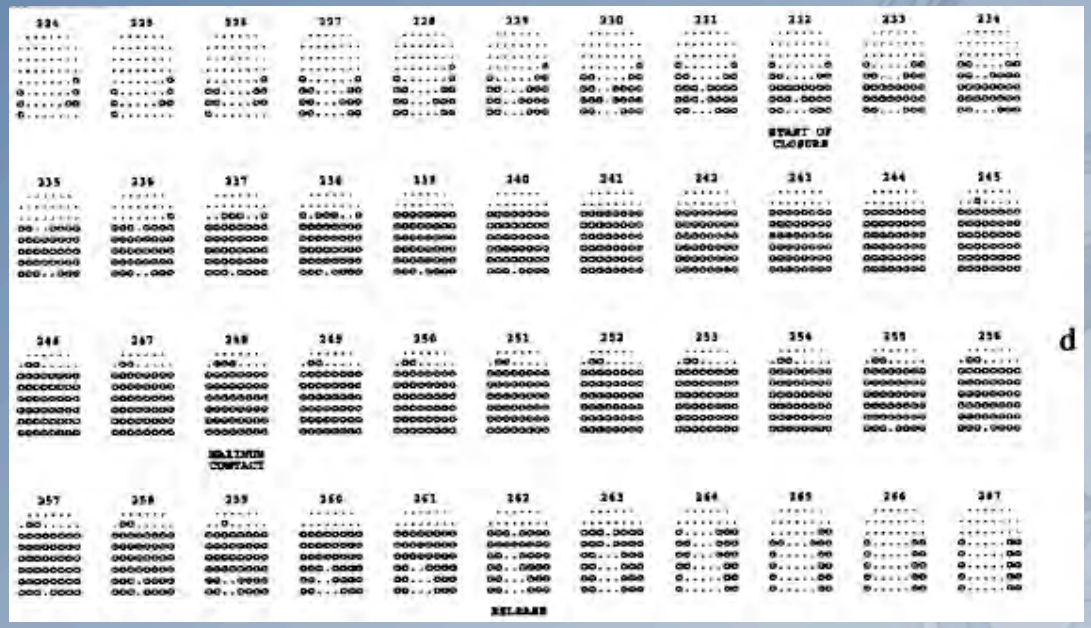
Both results suggest developmental differentiation between anatomically coupled articulators in young children's motor behavior.



Lip-jaw coordination begins to stabilize between ages 2 and 6

cf. Lingual Differentiation in disordered speech

"...ability of different tongue systems to function in a quasi-independent manner" (Gibbon 1999)



<– /d/ produced by a child with APD involves whole tongue constriction (from Gibbon & al. 1995)

An observation

English liquids /r/ and /l/ are hard to acquire
(Prather 1975, Locke 1983, Ingram 1989, etc.)

In L1 acquisition, substitutions often result:

- common substitutions for /r/:
  - [w], [j] (prevocalic): rabbit [wæbɪt, jæbɪt])
  - [schwa], [schwa^{w}] (postvocalic): ear [iə iə^{w}]
- common substitutions for /l/:
  - [w], [j], [d] (prevocalic): lady [weidi, jeidi, deidi])
  - [o], [w] (postvocalic): feel [fio, fiw]

A related(?) observation

Liquids are more ‘lingually complex’

- In English, only /r/ and /l/ have two lingual gestures*

/r/

/l/

*Possible exception: central + lateral margin control for sibilants (Stone & al. 1992), which are also acquired late.

Basic Principles

1. Complexity: Learning to differentiate anatomically coupled articulators (e.g., lip-jaw, tongue-tongue) is harder than learning to differentiate non-coupled articulators (e.g., lip-tongue, tongue-velum)

2. Transparency: Most segments in a language are little affected by lack of oral motor differentiation (e.g., an undifferentiated lip & jaw does not prevent /p/ closure)

3. Simplification: The entire tongue moves essentially as a single unit until differentiated, making only one constriction at a time

Proposal

That gestural simplification may dictate substitution strategies for liquid consonants has been suggested previously (Studdert-Kennedy & Goldstein 2003).

I propose that gestural simplification may be achieved via one of two basic mechanisms:

1. gestural omission
2. gestural merger/averaging

...and that these two mechanisms account for all of the commonly attested substitutions for English /r/ and /l/.

Some Predictions

1. Young children, motor delayed speakers, and some L2 learners will have difficulty with English l/r and will use simplification strategies
    - I.e., common substitutions should be lingually less “complex”
    - Should also apply to other productions that require lingual differentiation (e.g., C clusters)

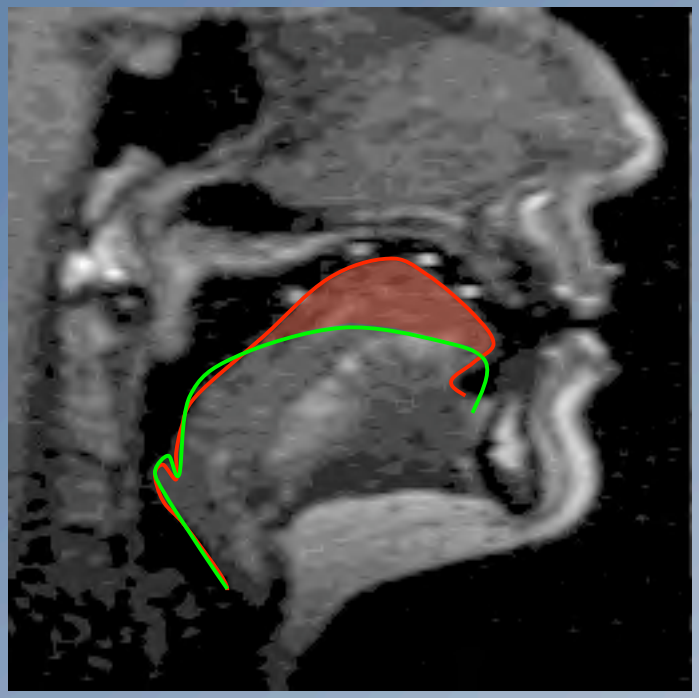
2. Hearing-impaired speakers may lack sufficient input to learn lingual differentiation
    - Implication: the tongue doesn’t “automatically” differentiate as part of general physical development

3. Cross-linguistically, we should see:
    - Late acquisition of other lingually complex sounds
    - Early acquisition of liquids that are lingually simplex

Gestural Omission (Anterior)

/r/ > schwa

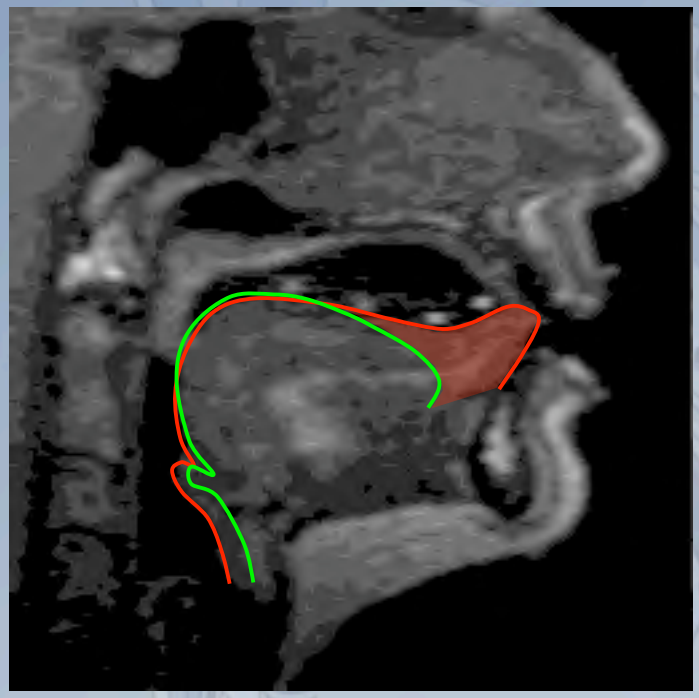
= loss of tongue body gesture



target = /r/ (red line)
substitution = schwa (green line)

/l/ > [w]

= loss of tongue tip gesture

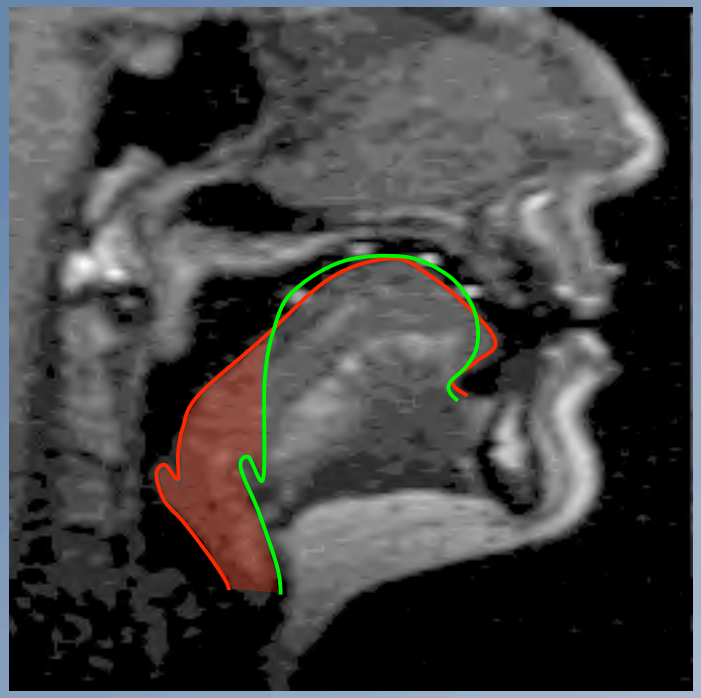


target = /l/ (red line)
substitution = /w/ (green line)

Gestural Omission (Posterior)

/r/ > /j/

= loss of tongue root gesture



target = /r/ (red line)
substitution = /j/ (green line)

/l/ > /d/

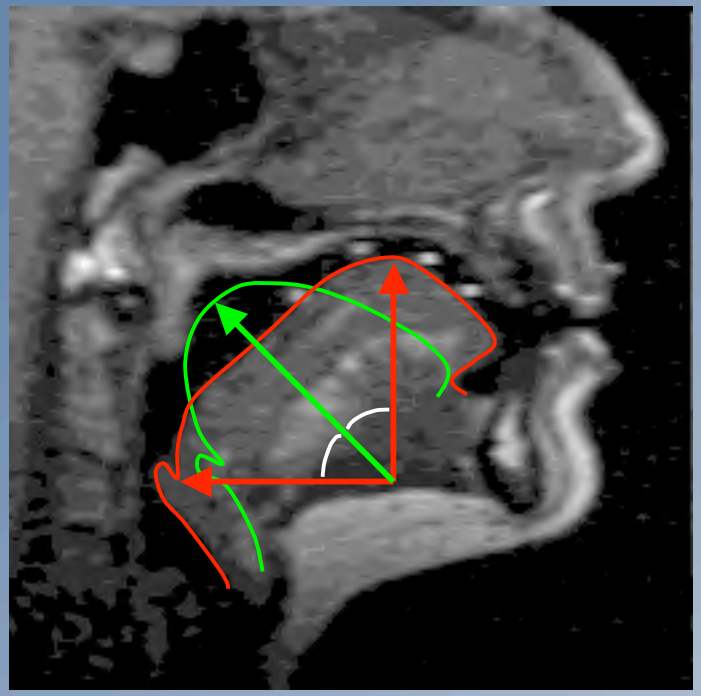
= loss of tongue dorsum gesture

target = /l/ (red line)
substitution = /d/ (green line)

Gestural Merger/Averaging

/r/ > /w/

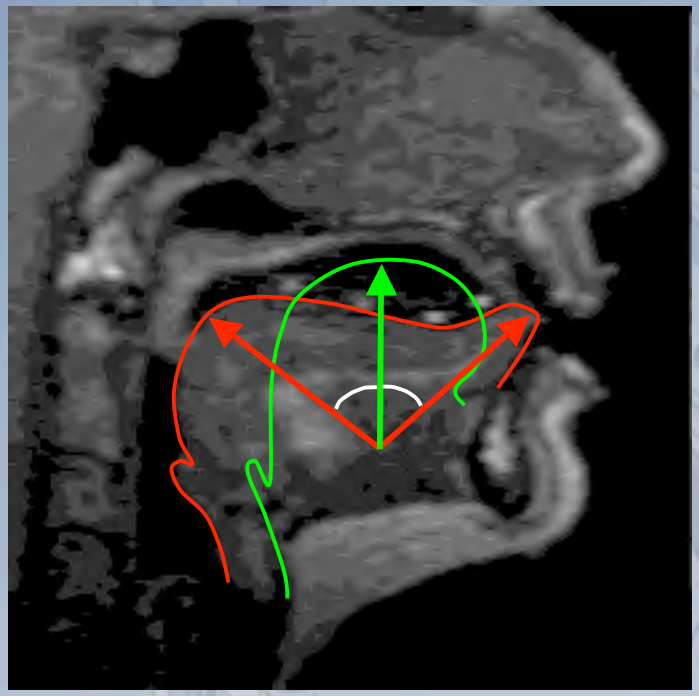
= loss of tongue root gesture



target = /r/ (red line)
substitution = /w/ (green line)

/l/ > /j/

= loss of tongue dorsum gesture



target = /l/ (red line)
substitution = /j/ (green line)

L1 /r/ (Gestural Merger)

LL (4;?)

L1 /r/ (TR Omission)

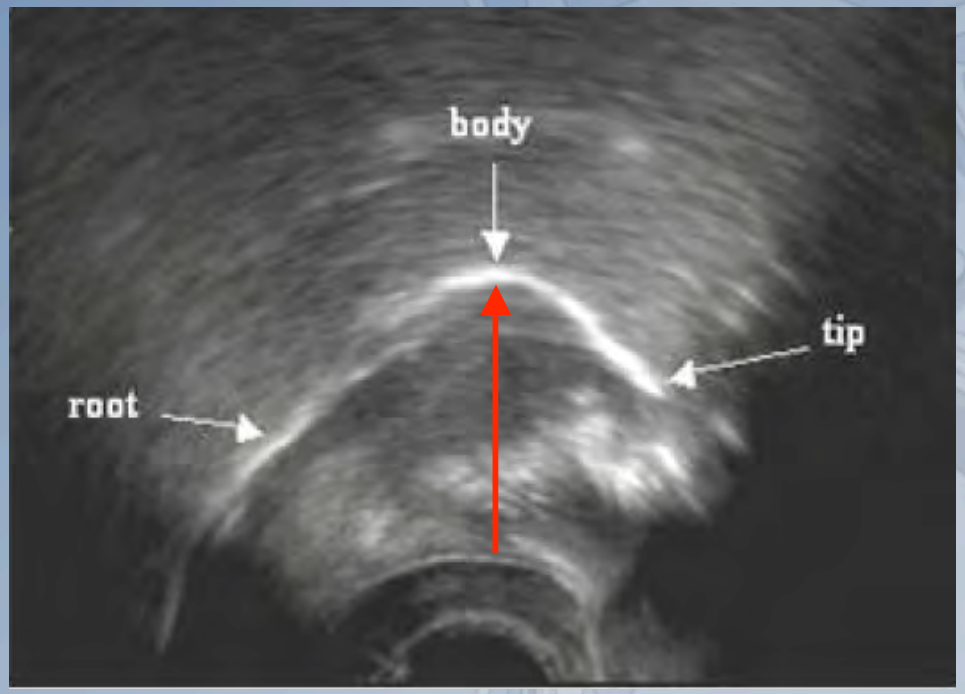
AD (4;4)

(N.B.: TT on LEFT in video)

Delayed /r/ (TR Omission)

(from Modha, Bernhardt, Church & Bacsfalvi in press)

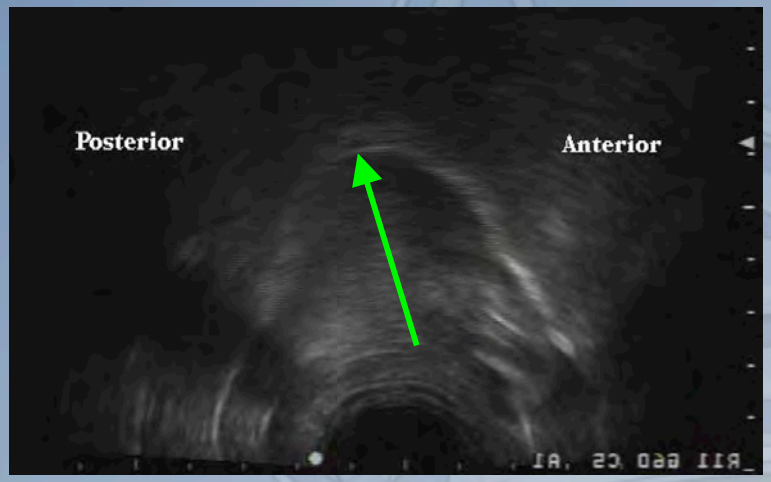
MB (13 yo)
/r/-specific delay
(possibly early
restricted frenulum)



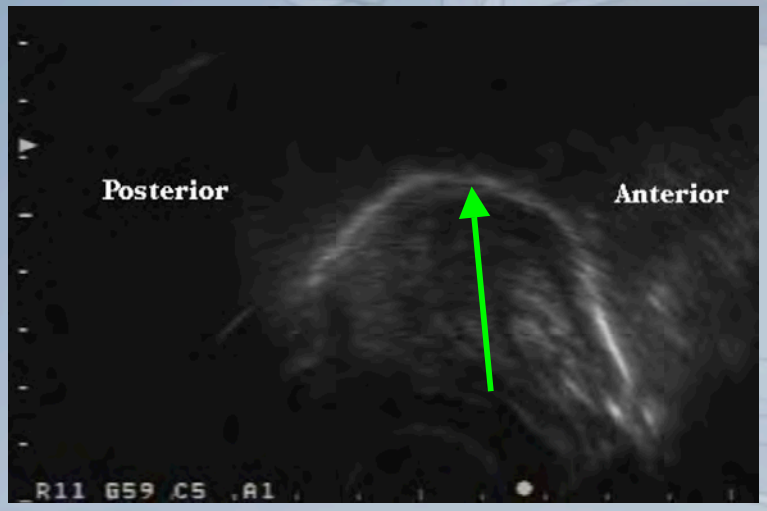
Delayed /r/ (Gestural Merger)

(from Modha, Bernhardt, Church & Bacsfalvi in press)

14 y.o. (VF)
/r/-specific delay

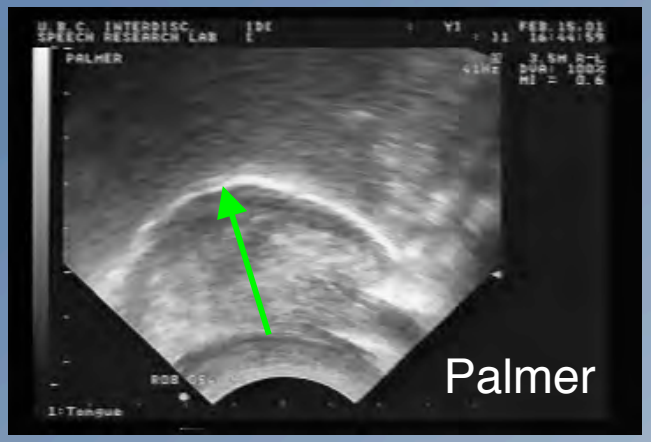


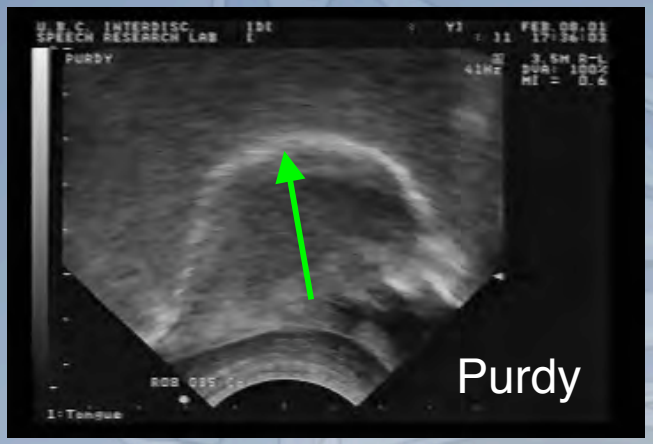
12 y.o. (ML)
/r/-specific delay

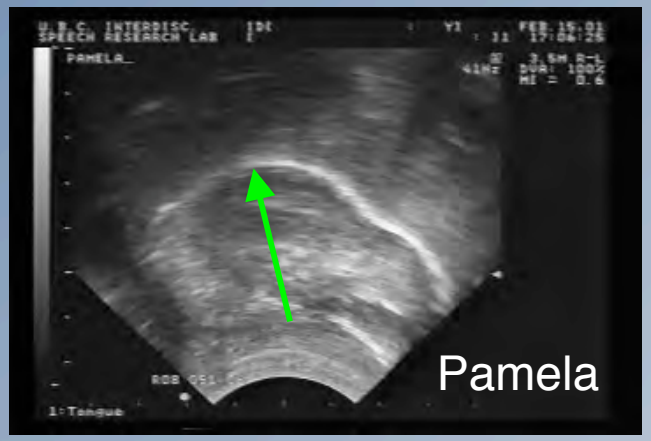


Hearing-impaired /r/ (Merger)

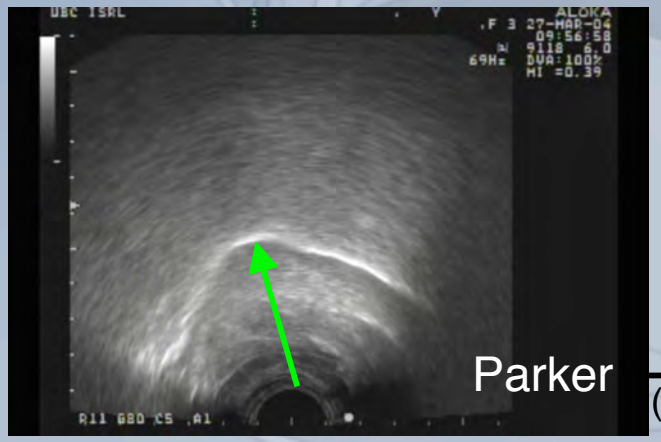
(from Bernhardt, Gick, Bacsfalvi & Ashdown 2003, etc.)







(Pamela: aided hearing up to 2000 Hz)



(video)

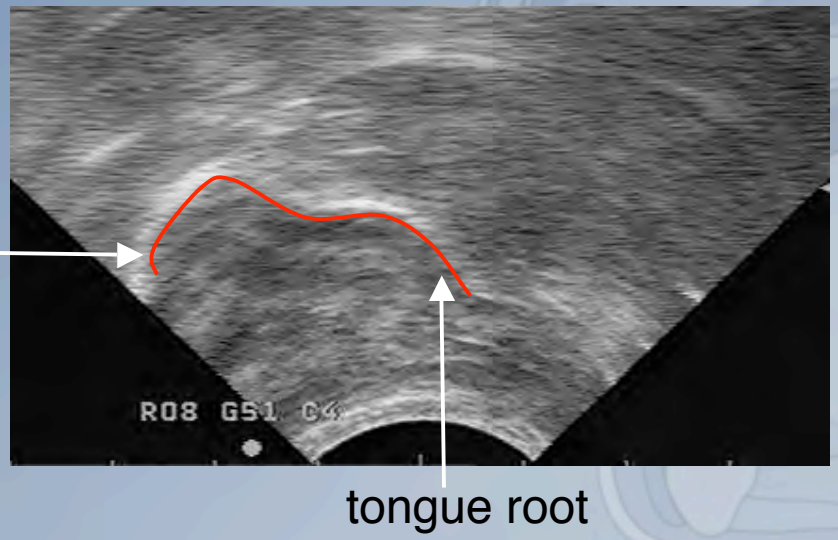
Hearing-impaired /r/ (Merger)

- Parker

Successful Early L1 /r/

Menard & al. (2007) argue that children need to use different articulations to produce adult-like acoustic results

A case study using ultrasound to image an 11.5-month-old female English speaker's tongue shows an adult-like overall tongue shape for postvocalic /r/ ('bear'):



Early L1 /r/

- AG (0;11.5)

(N.B.: TT on LEFT in video)

Cross-linguistically

...are lingually complex sounds acquired late?

√ Clicks: Acquired late (Herbert 1990)

√ Arabic: Pharyngealized C's acquired around 3:6

- Non-pharyngealized counterparts around 2 y.o. (Omar 1973, in Locke 1983)

√ Russian: Higher error rate for palatalized C's than non-palatalized C's in acquisition (Timm 1977, in Locke 1983)

- Except for /g^{j}/ and /k^{j}/ (which have the same phonological complexity but are lingually simple!)

Discussion

Results indicate that:

- Successful /r/ attempts correspond with differentiated tongue shapes, even for extremely young speakers
- Unsuccessful /r/ corresponds with undifferentiated shapes

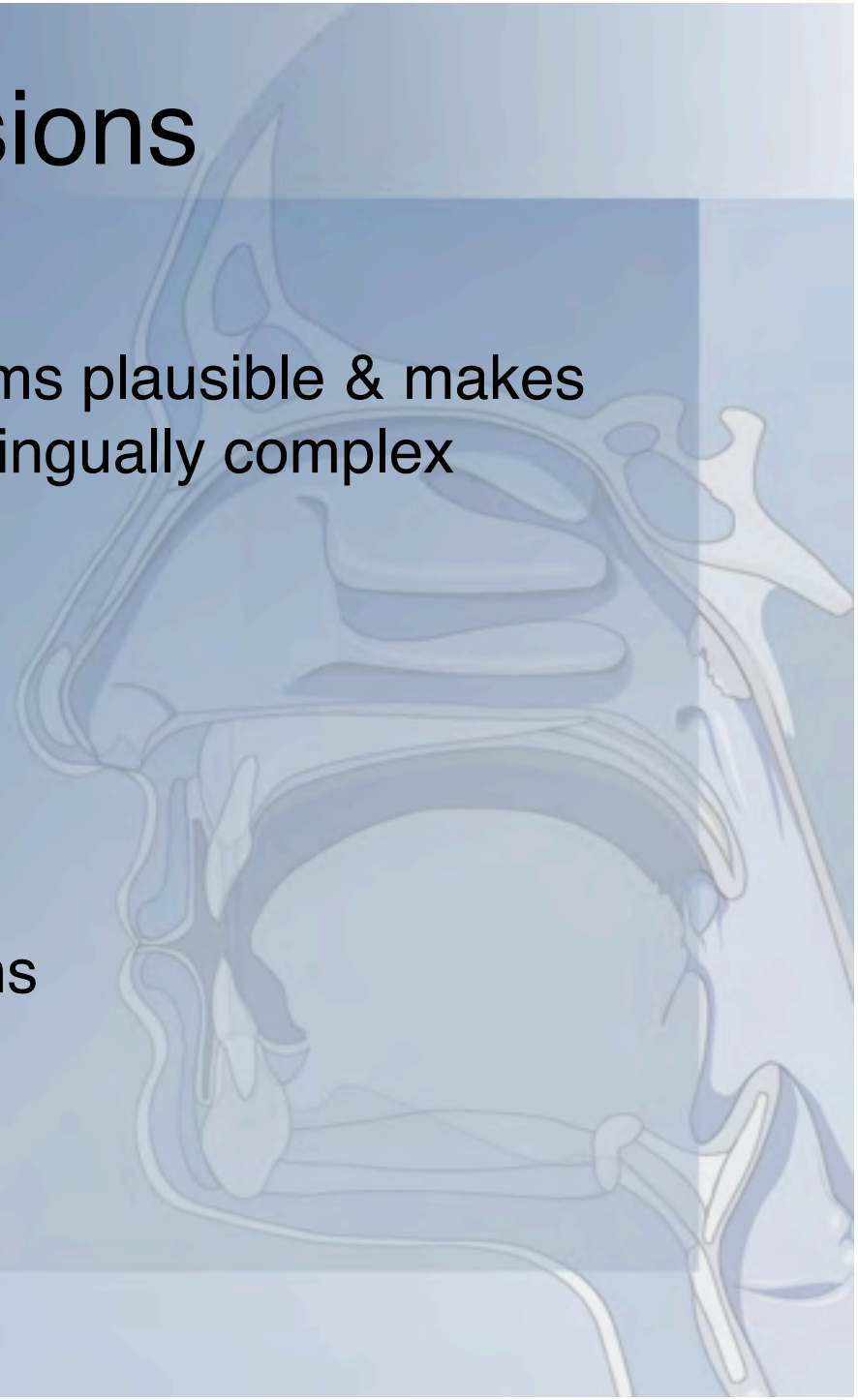
**Still need to quantify shapes (cf. coronal concavity)

- 4th-order polynomial fit to characterize degree of “dip”?
- “badness” of fit to arc?

Conclusions

The model presented here seems plausible & makes correct predictions concerning lingually complex consonants in terms of:

- L1 acquisition order
- common substitutions
- L1 difficulty with clusters
- hearing impaired speech
- cross-linguistic substitutions



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