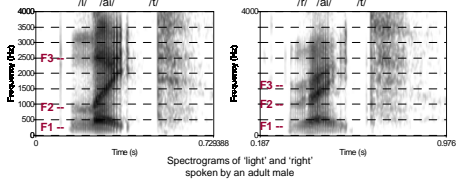
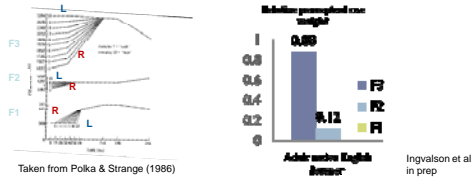


## Introduction

- /l/ vs /r/ distinction:** Acoustically, /l/ and /r/ are distinguished, *primarily*, by the onset frequency of the third formant (F3) (e.g., Lotto, Sato & Diehl, 2004)



- However, acoustics of speech are multidimensional.
  - Acoustically, onset F3, F2 frequency, F1 transition covary with /l-/r/ distinction (e.g., Polka & Strange 1986)
  - Perceptually, F3 is weighted more heavily than F2 or F1 transition is (Ingvalson, McClelland, & Holt in prep; Yamada & Tohkura 1993)



- Cue Weighting:** Listeners process multiple acoustic cues in perception (e.g., Francis et al, 2008; Holt & Lotto, 2005)
- Redundant information in speech signal is useful and perhaps necessary in processing variable and noisy signal
- Children have to learn to use appropriate acoustic cues with appropriate weighting
  - Phonetic development continues well into the childhood (e.g., Hazan & Barrett 2000; Nittrouer & Miller 1997)
- Development of /l/ and /r/:** Important development seems to occur between age 3 and 7.
  - Before age 3: children start producing /l/ and /r/, but with high frequency of variants (i.e., [w]). (Smit et al 1993); Onset F3 and F2 are still developing (McGowan et al 2004).
  - Around age 7: variant productions disappear (Smit et al).
  - Not much work examining the development of /l-/r/ distinction in terms of F2/F3 cue integration.

## Method

### Participants

Group	N	Age range	Mean age
Younger	12	3.95-4.37	4.16
Mid	13	4.42-5.04	4.71
Older	12	5.05-6.13	5.46
*8 Yr Old	11	7.31-9.54	8.45
*Adult	18	undergraduate	

\*Only perception data is analyzed so far

### Production tasks

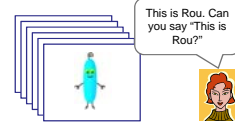
- Repetitions: /r/l/, /r/u/, /r/a/, /l/i/, /l/u/, /l/a/ in the frame "This is \_\_\_\_"
- Naming: /write/ and /light/ in isolation

### Perception task

- Categorization of 'light' and 'write'

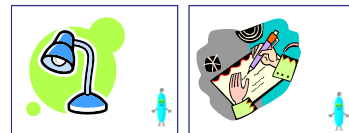
## Method (production)

### Repetition task



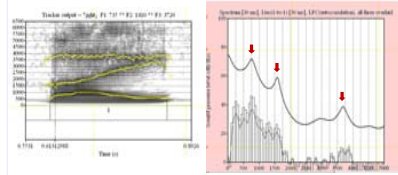
6 names (/r/i/, /r/u/, /r/a/, /l/i/, /l/u/, /l/a/)  
 x 5 repetitions  
 = 30 tokens

### Naming task



2 words (/write/ and /light/)  
 x 5 repetitions  
 = 10 tokens

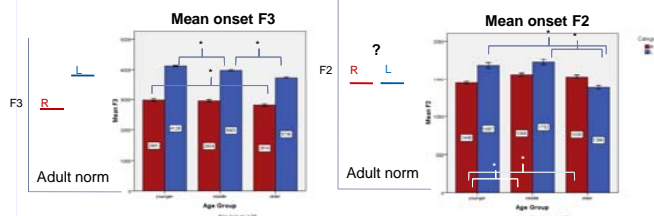
### Analysis



- F1, F2 and F3 were measured at visible peaks examining the spectrogram and LPC-smoothed spectrum.
- 10 ms Hamming window and 12 smoothing poles were used

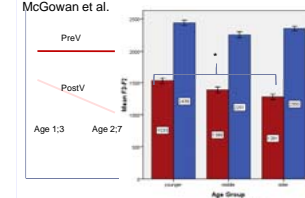
## Results (production)

### Production



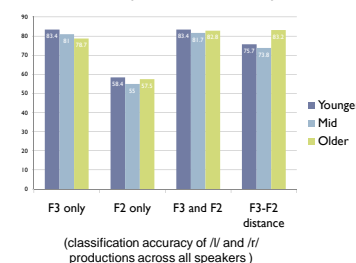
- F3 distinguished L and R productions in all groups.
- F2 decreased for L from Younger to Older children for both L and R.
- F2 increased for R from Younger to Older.

### F3-F2 distance from McGowan et al.



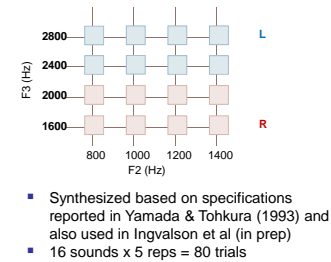
### F3-F2 distance decreased for R

### Preliminary Discriminant Analysis



## Method (perception)

### Stimuli



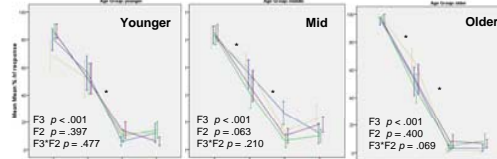
### Task



- Children heard the stimuli through headphones, and pointed to either picture to indicate which word they heard
- Location of the pictures were randomized
- 80 identifications / child

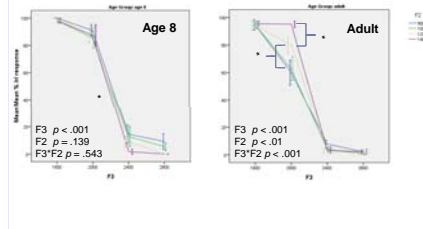
## Results (perception)

### % R responses



- Children use F3, but not F2 in the /l/ and /r/ categorization
- Response patterns become more consistent in the Older group

- From Older (age 5) to Age 8, the response shape become **steeper in the boundary area** (F3 = 2000-2400).
- Age 8 still does not show the use of F2 in the way adults do.
- Adults used F2 when F3 was ambiguous.
- Still not clear whether:
  - Greater F2 = more /r/ percept, or
  - Smaller F3-F2 distance = more /r/ percept



## Findings

- Although both F3 and F2 effectively differentiated /l/ and /r/ productions in children, these categories were still being refined and tuned at age 5 in terms of F2 and F3 values.
- Perhaps these refining and tuning are related to changes in category goodness of the child productions.
- F2-F3 distance may have a potentially important role (i.e., acoustic cue?) differentiating /l/ and /r/ categories.
- Although the perceptual pattern does become adult-like around age 8, the integration of the secondary cue (F2) was not observed in this oldest group.
- These findings are consistent with developmental work on the perception of other sounds (e.g., fricatives). Fine-tuning of speech categories continues through the childhood, sometimes till 10- and 12-yrs of age.

### Reference

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