Motor and perceptual precursors of speech production: A longitudinal study

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Clinical Context

- Developmental speech sound disorder (SSD) is a common communicative impairment of early childhood (Harrison et al., 2017)
  - Affects approximately 16% of all preschool-aged children (Campbell et al., 2003)
- Unresolved SSD can negatively impact:
  - Academic performance (Harrison et al., 2017)
  - Literacy (Nathan et al., 2004)
  - Social participation (Felsenfeld et al., 1994; Hitchcock et al., 2015)
- Early identification and intervention can minimize the likelihood of these difficulties (Harrison et al., 2017)

Factors Underlying Speech Production Errors

- **Phonological processing** - capacity for formation of abstract cognitive-linguistic categories
- **Motor skill** - ability to isolate and coordinate movement of the articulators in an efficient and controlled manner (Gibbon, 1999)
- **Perceptual skill** - ability to distinguish and classify sounds associated with speech categories (Shiller et al., 2010)

Perceptual Precursors of Speech Production

- Children with SSD often exhibit perceptual deficits associated with their production deficits
  - However, these children typically do not present with a global/generalized perceptual deficit (McReynolds et al., 1975; Rogow Waldman et al., 1978)
  - Rather, they tend to exhibit perceptual difficulties for speech sounds for which they also exhibit production difficulties
    (Hoffman et al., 1985; Locke, 1980; Rvachew and Jamieson, 1989)

Motor Precursors of Speech Production

- Skilled motor control of the speech structures is also a prerequisite for adult-like speech production
- Lingual differentiation as an index of motoric development:
  - Lingual differentiation is the ability to control anterior versus posterior parts of the tongue semi-independently
  - Using electropalatography (EPG) Gibbon (1999) has documented that:
    a. Children exhibit more undifferentiated gestures than adults
    b. School-aged children with SSD exhibit a higher percentage of undifferentiated gestures than typically-developing (TD) peers

Motor Skills: Lingual Complexity

- ► Ultrasound imaging
  - ► Can be used to view the shape of the tongue during speech
  - ► Degree of lingual differentiation, henceforth **lingual complexity**, can be quantified along a continuous scale
  - ► Studies focusing on lingual complexity have shown that (Klein et al., 2013; Preston et al., 2019):
    - ► Adolescents with residual speech errors exhibit less lingual complexity than age-matched TD peers
    - ► Adolescents with residual speech errors exhibit an increase in lingual complexity from pre- to post-treatment; this increase is positively correlated with an increase in production accuracy

Goals of the Current Study

- ▶ This study: longitudinal data from preschool-aged SSD population to track relative emergence of:
    1. Transcribed production accuracy
    2. Lingual complexity
    3. Perceptual skills
- ▶ Research questions:
    1. Is there an association between perceptual acuity and production accuracy in this dataset?
    2. Is there an association between a low-level index of motor skill (lingual complexity) and production accuracy in this dataset?
    3. Are there any associations between the timing of the relative emergence of motor skills and perceptual skills in this dataset?
- ▶ Hypotheses:
    1. Increases in perceptual skill will positively correlate with increases in production accuracy
    2. Increases in motor skill will positively correlate with increases in production accuracy
    3. Increases in perceptual skill may precede increases in motor skill

Participants

- Four children ages 4;0 - 5;11
- SSD as defined by standard score <80 and minimum 3 candidate patterns on HAPP-3 (Hodson, 2004)
- Average receptive language
    - Receptive Language Index of the CELF P-2 (Wiig et al., 2004)
    - PPVT-4 (Dunn and Dunn, 2007)
- Normal hearing

	302	303	305	2005
Age	4;2	5;1	5;4	4;1
Gender	M	F	M	F
HAPP-3	<55	<55	<55	76
Targets	/k/, /ɹ/	/k/	/k/, /l/, /ɹ/	/l/, /ɹ/
PPVT-4	136	99	113	111
CELF-P2 (receptive)	127	93	98	88

Design

- Longitudinal case series with 6 weeks of treatment and 6 weeks of no treatment *(counterbalanced across participants)*
  - Treatment condition:
    - 3 treatment sessions per week (~30-45 mins.) of individual treatment provided by a certified SLP
    - One probe measure administered at start of each treatment session (~15 mins.)
  - No-treatment condition:
    - one visit per week elicited all three probes

Cycles Treatment (Hodson and Paden, 1983, 1991)

- Mimics typical development by cycling through multiple targets, organized by phonological pattern, not requiring mastery to move to next target
- Activities include auditory bombardment, a phoneme awareness task, and articulatory drill-play
- Cycles was chosen for this study because it has documented efficacy (Rudolph and Wendt, 2014) and is widely used for children who present with a variety of speech error patterns

Word Production Probes

- Treatment targets for each participant were 3 phonological error patterns meeting HAPP-3 criterion occurring in at least 40% of relevant contexts; at least one pattern involves a lingual singleton consonant target (/ɹ/, /l/, /k/)
- Varied phoneme probe (ultrasound and audio recordings):
  - Varied lingual singleton consonants in initial position (48 total items in standard probe)
- Individualized word probe (audio recordings):
  - Custom picture-word list (18 items specific to the child's error patterns)
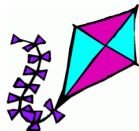
kite

yam

rake

Perception Probe

- SAILS (AVAAZ Innovations, 1994) for /l/, /ɹ/, /k/
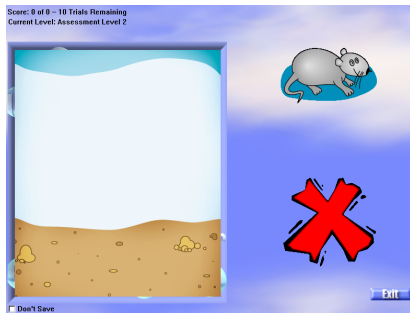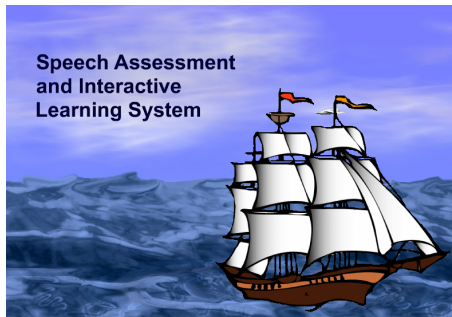
Measurement - Production Accuracy

- For all targets in the audio recordings, we determined perceptual ratings of accuracy based on transcriptions using Phon (Hedlund and Rose, 2016)
  - Two trained student transcribers and a consensus transcriber:
    - Correct (transcription = target)
    - Distortion
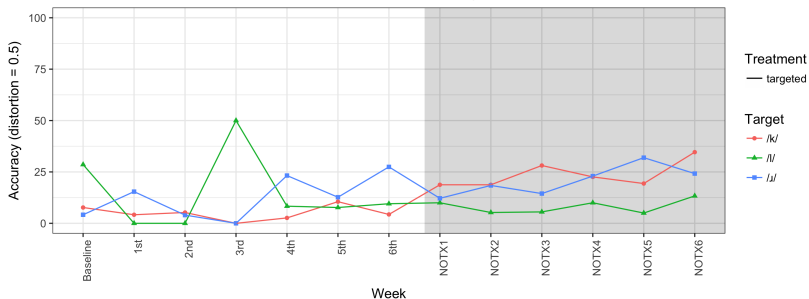   - Incorrect (substitution/omission)
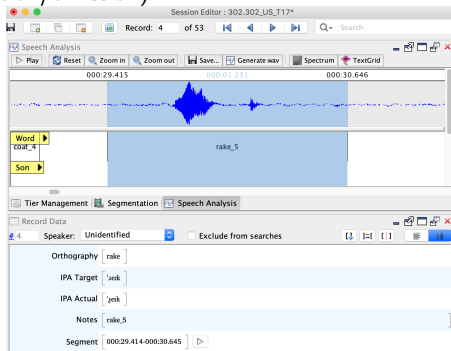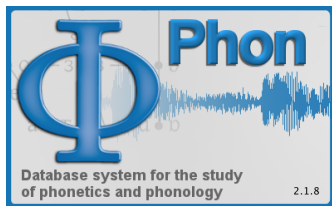
Measurement - Ultrasound

- ▶ Processing of ultrasound images:
  - a. Tracking in GetContours (Tiede, 2016)
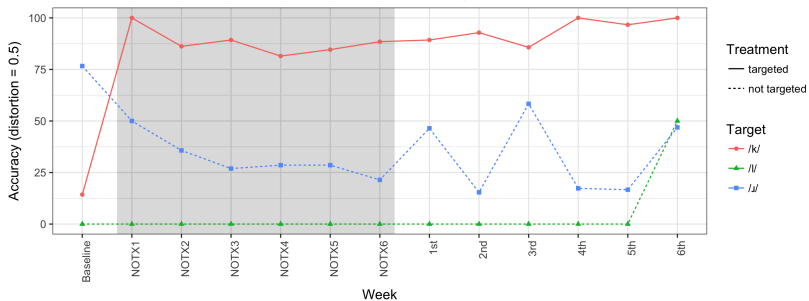 - b. Calculation of Modified Curvature Index (MCI) (Dawson et al., 2016; Dawson, 2016)
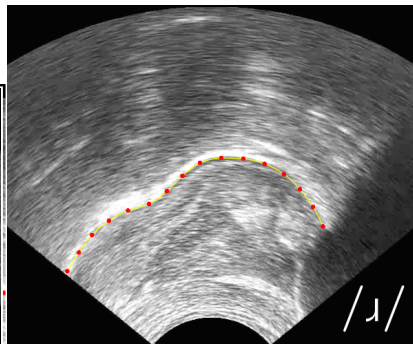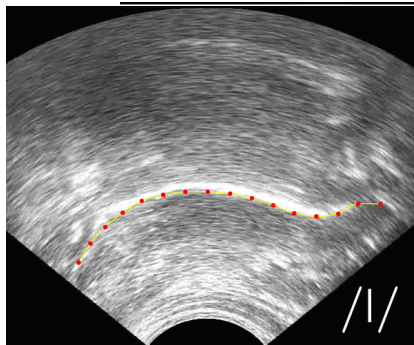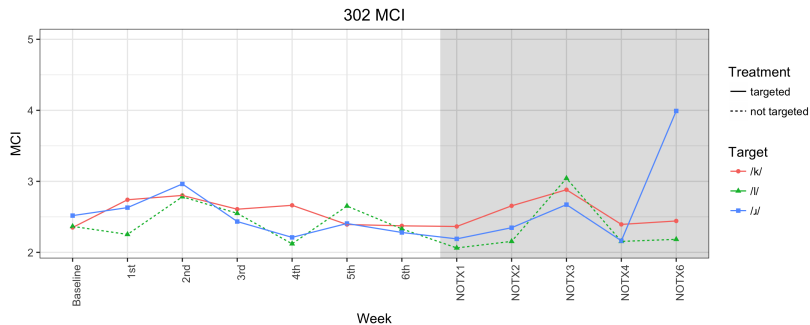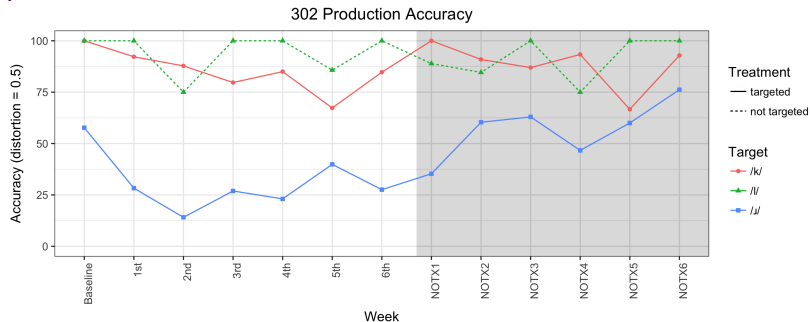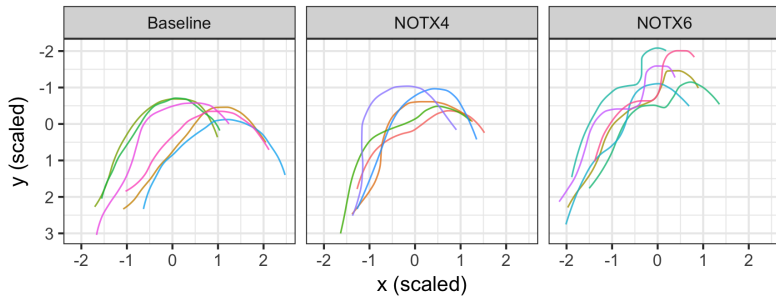
Two Non-Responders: 303 & 305

Responder: 302

302 /ɹ/ Tongue Shapes by Session

302 Baseline and Final Sessions

Responder: 2005

2005 Production Accuracy

2005 MCI
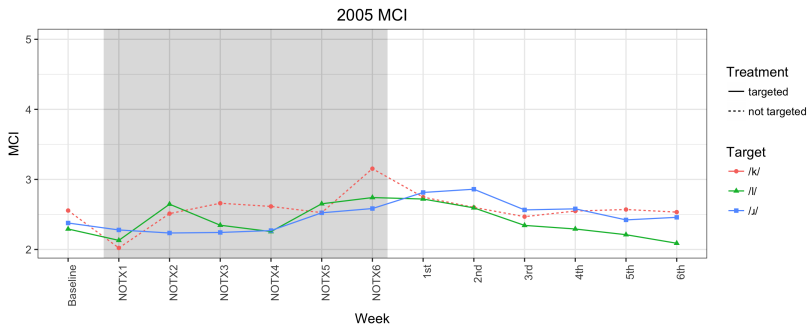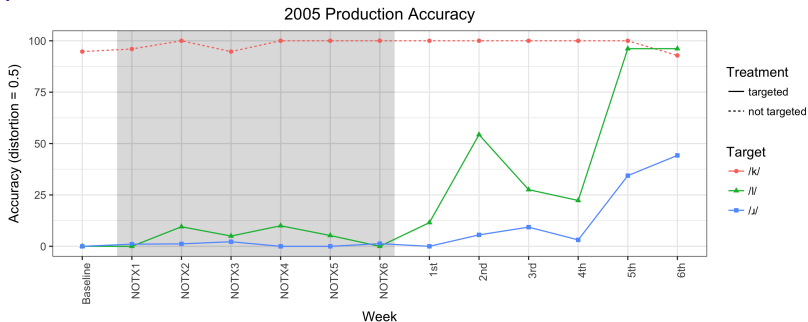
SAILS Perceptual Accuracy vs. Production Accuracy

SAILS by Production Accuracy
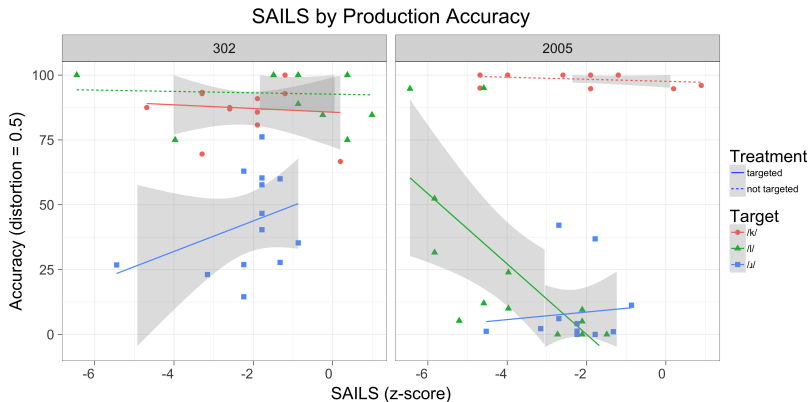
Findings

- ▶ Relationship between perceptual attunement and articulatory maturation in relation with changes in transcribed production accuracy was heterogeneous in our sample
- ▶ Failed to find evidence that changes in one domain reliably precede changes in another (e.g., perception must improve for changes in production to take effect)
- ▶ **Speech acquisition does not adhere to a neat and orderly developmental progression across domains**
    - ▶ Various articulatory-perceptual-motoric pathways to achieving adult-like production

The Case of 2005

- How do we account for cases that show the opposite of the predicted association for both perception and lingual complexity?
  - MCI findings could be suggestive of different articulatory strategies for producing a perceptually correct /l/ (and /ɹ/)
  - In a similar way, SAILS findings could reflect that child has idiosyncratic weighting of perceptual cues that enable achievement of perceptually acceptable /l/ despite not having robust perceptual representation

Strengths & Limitations

- Strengths:
    - Unique multidimensional dataset
    - Longitudinal design
- Limitations:
    - Children's attention/compliance was variable, particularly given the demanding nature of these tasks administered repeatedly
    - Orientation of ultrasound images
    - A longer study duration would allow us to observe larger magnitude of change
    - Choice of Cycles treatment?
    - Need more data!

Future Directions

- With more participants, can we identify groupings based on skill sets?
- Compare with TD for differences in:
    - Magnitude of change
    - Timing of emergence

Thank you!

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