CHARACTERIZING SENSORIMOTOR PROFILES IN CHILDREN WITH RESIDUAL SPEECH ERRORS

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INTRODUCTION

- Most children with speech sound disorder recover, but ≈25% show persisting errors past age 6 [1]; ≈1-2% continue with residual speech errors (RSE) into adolescence and beyond [2].
- Ability to predict when errors will persist is crucial for evidence-based clinical decision-making.
- Children with reduced motor skill are considered most likely to develop persistent errors [3], but the means available for measuring motor involvement are limited.
- The objective of this study is to evaluate **tongue complexity as a potential measure of motor skill** while examining the **relationships among sensorimotor factors** in children with RSE.
  - We measured tongue complexity before & after treatment for rhotic targets; we also collected measures of somatosensory and auditory function.

OBJECTIVES

1. Quantify the relationship between tongue complexity and perceived accuracy of speech.
   Hypothesis: higher tongue complexity associated with greater perceived accuracy
2. Determine if somatosensory acuity and tongue complexity are related (controlling for auditory acuity).
   Hypothesis: higher somatosensory acuity associated with higher tongue complexity

Understanding the connection between motor skill (via tongue complexity) and sensory capacity may offer insight into how these skills cooperate during speech.

TONGUE COMPLEXITY

- According to current models of speech production, speech is produced by executing a stored motor plan [e.g., 4].
- "Motor skill" can refer to the robustness of the feedforward plan.
  - Degree of differential control of anterior & posterior lingual regions connected with achievement of adult-like speech [5].
- Degree of lingual differentiation was approximated by using ultrasound-based indices of "tongue complexity."
  - Modified curvature index (**MCI**) [6] is the integral of absolute curvature (reciprocal of the tangent circle) at each point.
    - *For adults, higher MCI values in phonemes with multiple constrictions (/ɹ,l/) than single constriction (/æ,ɪ/) [6].*
  - Number of INFLection points (**NINFL**) [7] is the number of thresholded curvature sign changes along the contour.
    - *For children producing /ɹ/, higher NINFL based on classification (TD > RSE), accuracy (correct > incorrect), and treatment (post > pre) [7].*

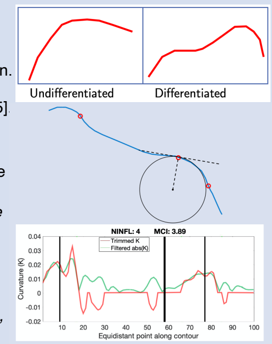


Figure: MCI is the area under the filtered absolute curvature (green line); NINFL is represented by trimmed curvature (red line), which increases from one for each sign change (from + to - or vice versa).

SOMATOSENSORY ACUITY

- Somatosensory and auditory feedback modulate speech production [e.g., 4].
  - **Somatosensory and auditory acuity are distinct sensory factors** that influence speaker's ability to access and respond to feedback in that domain in order to update motor plans [8].
- Focus is **somatosensory acuity** while controlling for the better-studied covariate **auditory acuity**.
  - Somatosensory acuity should correlate with tongue complexity based on evidence that:
    - Tongue complexity is lower in children with RSE than TD peers [7].
    - Somatosensory acuity is lower in adolescents with RSE than TD peers [9,10].
  - We used an **oral stereognosis task** in which children used their tongue tip to identify various sizes of capital letters on plastic strips [11].
    - Letters presented in an adaptive staircase fashion where size decreased after correct and increased after incorrect responses.
    - Score is average size of correct responses.
    - Stereognosis **measures tactile acuity**; other tasks may also tap into proprioceptive somatosensory acuity [12].

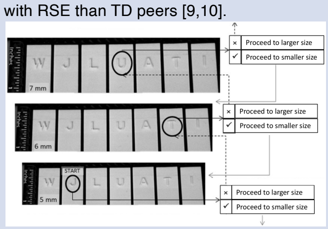
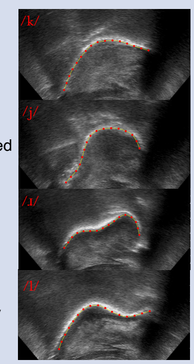


Figure: Plastic letter strips from oral stereognosis task; adapted from [13] with permission.

METHODS

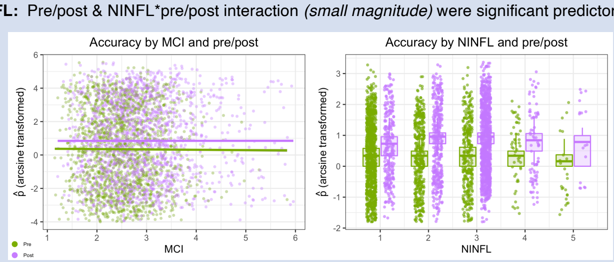
- **Participants:** 34 children ages 9;0-14;7 (μ = 10;7) with RSE affecting American English /r/ received 10 weeks of ultrasound biofeedback treatment (2-3 sessions/wk) at NYU/Haskins
- **Word production probe administered at pre- & post-treatment:**
  - Consonantal, syllabic, & vocalic /r/ in phonetically balanced word list
- **Perceptual accuracy ratings**:
  - Obtained 9 ratings [13], calculated mean rating ($\hat{p}$), arcsine transformed
- **Tongue complexity calculated from 100 x-y coordinates:**
  - Ultrasound video (Siemens C8-5 transducer) via video capture card
  - Label /r/ interval in Praat [14]; track tongue shape in *GetContours* [15]
  - Extract coordinates from target frames; calculate MCI [6]/ NINFL [7]
- **Measuring sensory acuity** *(auditory acuity at pre-treatment)*:
  - *Somatosensory acuity*: Mean letter size in stereognosis task [11]
    - *smaller letter size = increased somatosensory acuity*
  - *Auditory acuity*: Perceptual boundary width on "rake"- "wake" auditory identification task from [16]
    - *smaller boundary width = increased auditory acuity*



RESULTS

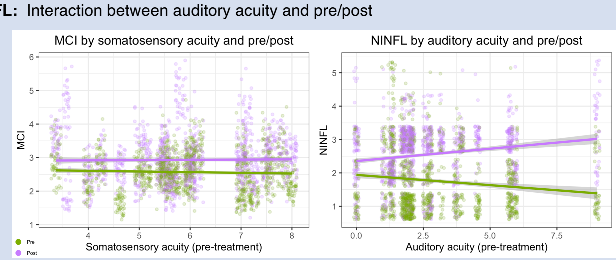
1) Are tongue complexity and perceived accuracy related?

- Linear mixed-effects regression predicting accuracy (arcsine transformed $\hat{p}$) from tongue complexity
  - Separate models for MCI and NINFL
  - Fixed effect of pre/post; random effects (child, word)
- **MCI:** Pre/post, & MCI*pre/post interaction *(small magnitude)* were significant predictors
- **NINFL:** Pre/post & NINFL*pre/post interaction *(small magnitude)* were significant predictors



2) Are somatosensory acuity and tongue complexity related?

- Linear mixed-effects regression predicting tongue complexity from somatosensory acuity
  - Separate models for MCI and NINFL
  - Fixed effect of pre/post; controlling for auditory acuity; random effects (child/word)
- **MCI:** Interaction between somatosensory acuity and pre/post *(small magnitude)*
- **NINFL:** Interaction between auditory acuity and pre/post



CONCLUSIONS

Q1 Findings:

- Perceived accuracy was significantly higher at post-treatment than at evaluation.
- Small magnitude interaction between tongue complexity and pre/post suggests that association between tongue complexity and perceived accuracy was slightly higher at post-treatment than at pre-treatment (but limited association in either case).

Interpretation

- Previous research has shown a positive association between tongue complexity and accuracy [7]; unclear why not significant in the present sample.

Q2 Findings:

- Poorer acuity associated with *less complex* tongue shapes at pre-treatment, but *more complex* tongue shapes at post-treatment.
  - **MCI:** Interaction between *somatosensory acuity* and pre/post *(small magnitude)*
  - **NINFL:** Interaction between *auditory acuity* and pre/post
- **Interpretation:**
  - Possible compensation for decreased acuity derived from ultrasound treatment.
  - Unclear why auditory acuity showed strong time-based relationship with NINFL.

Next steps

- Explore *proprioceptive* acuity as more important than *tactile* acuity for /ɹ/.
- Test whether there is an association between tongue complexity and acoustically measured accuracy (Q1); Determine whether time-based association between tongue complexity and auditory acuity is robust (Q2).

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