# 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 and auditory function.

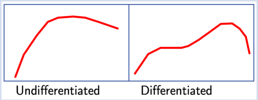
### OBJECTIVES

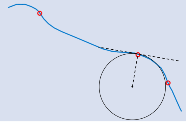
1. Quantify the relationship between tongue complexity and perceived accuracy of speech.
   *Hypothesis: higher tongue complexity associated with greater perceived accuracy*
2. Determine if somatosensory acuity and tongue complexity are related (controlling for auditory acuity).
   *Hypothesis: higher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





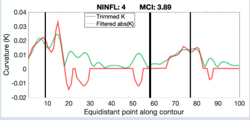


*Figure: MCI is the area under the filtered absolute curvature (green line); NINFL is represented by trimmed curvature (red line), which increases from one for each sign change (from + to - or vice versa).*

## 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].

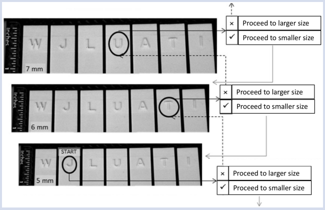
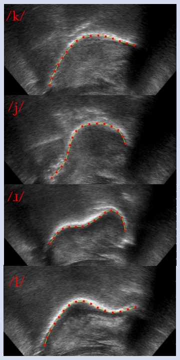


*Figure: Plastic letter strips from oral stereognosis task; adapted from [13] with permission.*

## METHODS

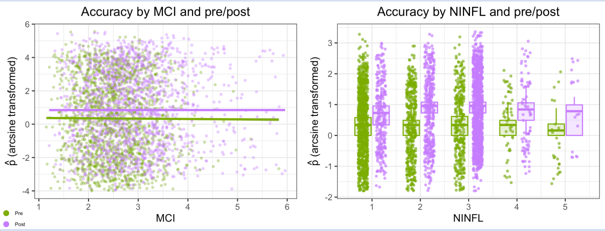
- **Participants:** 34 children ages 9;0-14;7 (μ = 10;7) with RSE affecting American English /r/ received 10 weeks of ultrasound biofeedback treatment (2-3 sessions/wk) at NYU/Haskins
- **Word production probe administered at pre- & post-treatment:**
  - Consonantal, syllabic, & vocalic /r/ in phonetically 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

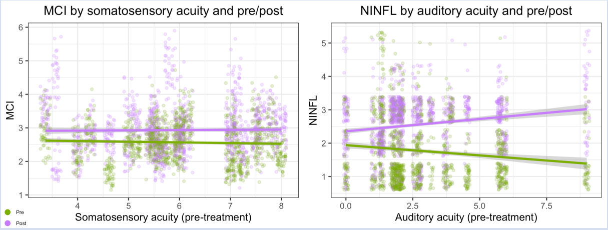
### 1) Are tongue complexity and perceived accuracy related?

- 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 /r/.
- 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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