EXTENDING LINGUAL COMPLEXITY MEASURES TO SPEECH DEVELOPMENT AND DISORDERS

Heather Campbell, MS, CCC-SLP[1]; D.H. Whalen, PhD[2,3,4]; Tara McAllister, PhD, CCC-SLP[1]
[1]New York University [2]The Graduate Center, City University of New York [3]Haskins Laboratories [4]Yale University

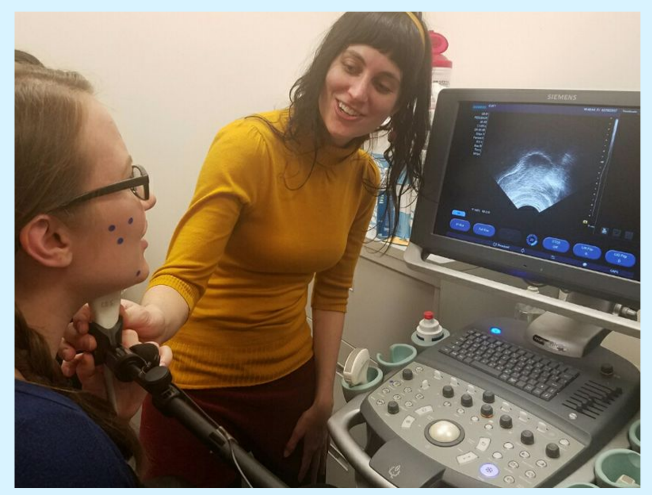
INTRODUCTION

- Broad generalizations about the order of acquisition of speech sounds are represented by normative values. [1]
- Developmental speech patterns reflect both phonological knowledge [2;3] and motor control of speech structures; relative contribution from these two domains is not fully understood [4].
- In early stages of development [5] and disorders [6], the inability to isolate control of anterior versus posterior regions may predict children's non-adult-like speech patterns.
- Speech productions may be sorted by degree of articulatory complexity [7].
  - Articulatory markedness and order of acquisition may be associated with degree of lingual complexity.

This study aims to explore the utility of several methods for measuring the degree of complexity of lingual contours in children and adults.

QUESTIONS

1. Do children differ from adults in lingual complexity when producing a variety of phonemes?
2. Do correct and incorrect /ɹ/ productions produced by child speakers differ in lingual complexity:
   a) Within typically developing (TD) children?
   b) Within children with speech-sound disorder (SSD)?



ADULTS

Dawson, Tiede, & Whalen (2016) [7]

- Asked which metrics best separated adult phonemes into complexity classes.
- Used *a priori* categories of complexity:
  - Low: /ɑ/, /æ/, /ɪ/, /ʌ/, /ɛ/
  - Medium: /w/, /u/, /j/, /g/
  - High: /d/, /l/, /ɹ/, /θ/, /ʒ/
- Used three techniques to sort tongue contours into complexity categories.
  - Modified Curvature Index (MCI)
  - Procrustes Analysis
  - Discrete Fourier Transform (DFT)

CHILDREN

METHOD

- Elicited target phonemes in words from 19 children ages 4;0-6;3 (mean = 5;0).
- Used GetContours [8] to track best frame within sonorant, vowel, & stop intervals (Fig 1).
- Computed lingual complexity metrics [9;10]

1280 tokens

- /æ/ (cat, lamb, rat, yam)
- /ɪ/ (ring, wing)
- /w/ (wake, wing)
- /j/ (yam)
- /k/ (cape, cat, coat, key)
- /t/ (tape, tea, toe)
- /l/ (lake, lamb)
- /ɹ/ (rake, rat, ring, rope)

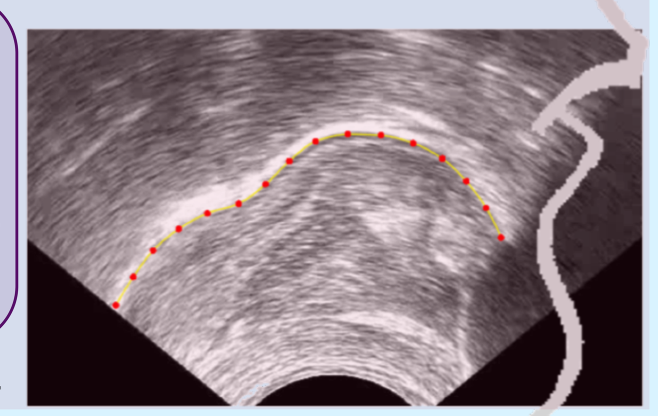


Fig 1 (right). Points were tagged along each lingual contour. Pictured in this image is an /ɹ/ production within the word "rake."

What is an intuitive measure of tongue complexity?

- In [7], Procrustes and especially DFT metrics did not correspond with intuition.
- MCI does correspond with intuition: high values are visibly more complex.
  - *MCI is an averaging technique that integrates curvature with length of the arc [11] and minimizes difference between two adjacent points.*
- The number of inflection points (**NINFL**) [10] is also intuitive. (Fig. 2)

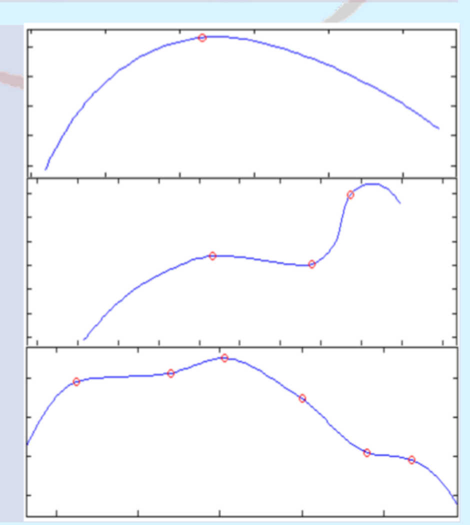


Fig 2 (right). Example contours demonstrating relationship between number of inflection points and complexity of lingual contours, from [10].

COMPARING CONTOURS

How well did MCI and NINFL separate child from adult targets?

- Linear mixed effects regression for MCI [12] & ordinal mixed effects regression [13] for NINFL.
- Group * phoneme interaction:
  - Adult and child /æ/ and /ɪ/ productions did not differ based on MCI/NINFL.
  - Adult and child /w/, /t/, /l/, & /ɹ/ differed based on MCI/NINFL.
  - Adult and child /k/ & /j/ differed based on MCI alone.
- Suggests that child and adult targets differ in lingual complexity, and this difference increases in more complex targets.

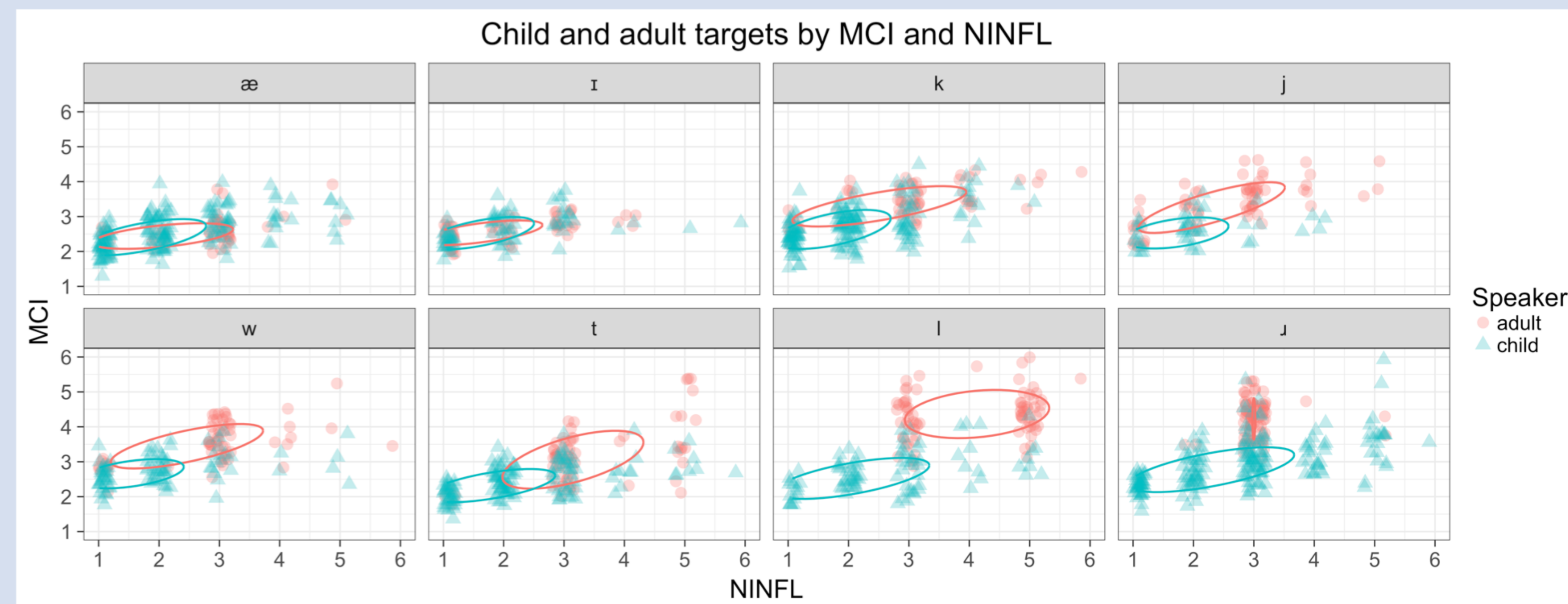


Fig 3. MCI & NINFL lingual complexity metrics by phoneme for both adult and child samples. Ellipses represent 50% confidence intervals.

How well did MCI and NINFL separate /ɹ/ productions by accuracy in children who are TD and those with SSD?

- Mixed effects logistic regression [12] for TD children only.
  - MCI was higher in correct than incorrect productions. *$z = 2.63$ ($SE = 0.31$), $p = 0.008$*
  - NINFL was not significantly associated with accuracy. *$z = 1.66$ ($SE = 0.16$), $p = 0.098$*
  - Suggests that correct productions have greater lingual complexity than incorrect productions in TD children.
- For children with SSD, lack of separation between correct and incorrect, though too few data points and children (n = 3) to test statistically.

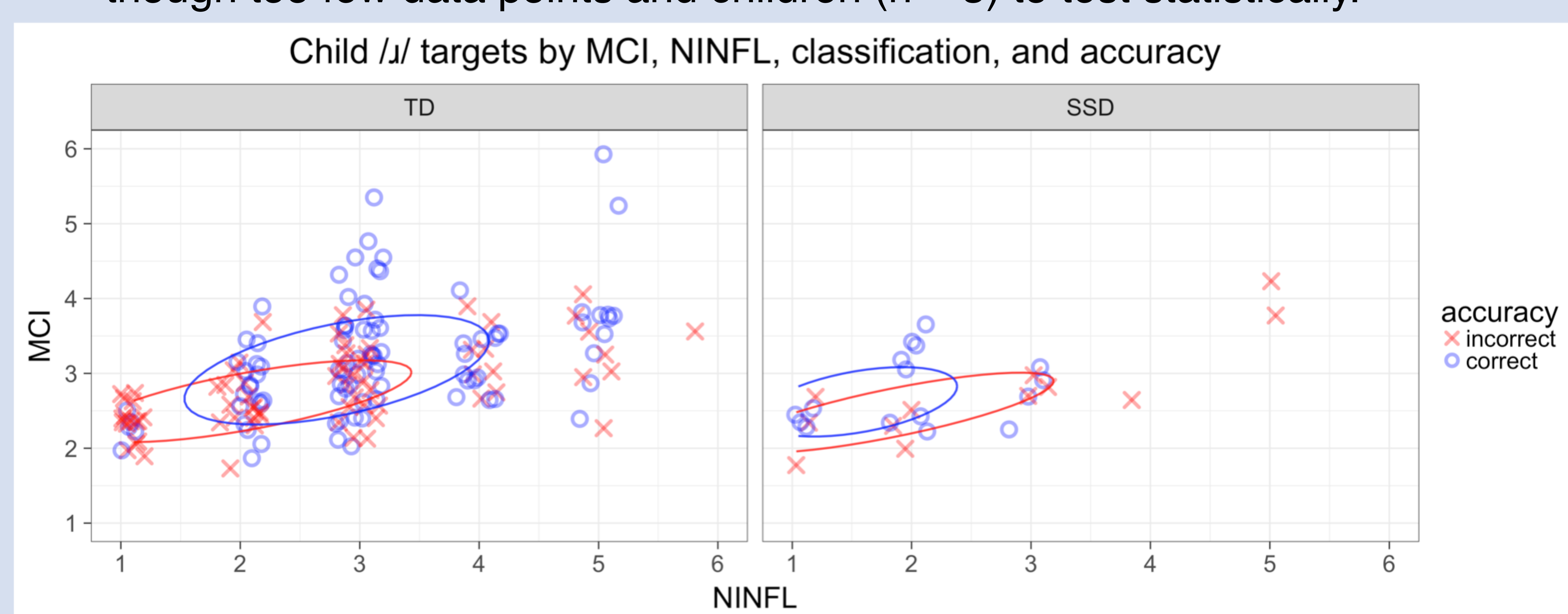


Fig 4. MCI & NINFL lingual complexity metrics for /ɹ/ in children who are TD and with SSD, grouped by perceptual accuracy, as scored by treating clinician. Ellipses represent 50% confidence intervals.

CONCLUSIONS

Impact

- The present study highlights the utility of ultrasound for measurement of lingual complexity in children.
  - Provides insight into motor development beyond what perceptual ratings can reveal.
- Strong parallel with [6], which suggested that undifferentiated tongue gestures, as measured with EPG, are an aspect of typical development and can provide insight into motor development.
  - Differences in lingual complexity between correct vs incorrect productions could point to a way to distinguish *developmental errors that will resolve* from those *errors likely to develop into SSD.*

Dissociation between TD & SSD?

- **TD**: Some accurate with low lingual complexity; others inaccurate with high lingual complexity.
  - Undifferentiated gestures as pervasive developmental phenomenon even when not overtly misarticulating, as in [6].
- **SSD**: Little separation of lingual complexity between correct and incorrect suggests globally reduced lingual complexity, need more data!

Additional clinical relevance

- In the future, these measures could be useful in clinical research and practice:
  - Recommendations for motoric vs. phonologically-oriented treatment approach.
    - Acoustic vs ultrasound biofeedback therapy
  - Quantify a baseline level of lingual complexity and track progress over the course of treatment.

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