Oral Presentation #6
Clinical Analysis of Speech Rhythms in Language Development using MATLAB

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Problem Statement

Preliminary research has been conducted that indicates a correlation exists between an individual’s rhythmic capabilities and language development.

Currently, the data analysis process used to determine an individual’s rhythmic abilities is inefficient and impractical in a clinical setting.

No data analysis process or system exists to assess an individual’s speech rhythm. There is a need in the industry for a diagnostic technique that efficiently analyzes the individual’s recorded speech to determine whether their rhythm is considered good or bad.

There is an immediate need in the Gordon lab for a data analysis process that quickly and efficiently judges rhythm in speech. Beyond the Gordon lab, there is a clinical need for a device with an intuitive interface that is capable of immediate analysis and display of feedback.
Needs Assessment

- Must (simultaneously):
  - Detect the rhythm of the English language
  - Detect the rhythm of musical metronomes
- Must streamline data in one software program
- Must reduce time needed to analyze data
- Must use consistent analytics
- Must provide feedback to user and lab staff
- Must have intuitive interface
- Must store data for future analysis and retrieval
- Must be safe, physically compatible with children, and comfortable
Specific Language Impairment

- A “disorder that delays the mastery of language skills in children who have no hearing loss or other developmental delays” [1]
- About 7-8% of kindergartners have SLI
- The cause is unknown but there does seem to be a genetic link
- Symptoms:
  - Beginning to talk after 2 years of age
  - Not being understood after 3 years of age
  - Difficulty with verbs- dropping the ‘s’ in present tense, avoiding past tense, etc.
  - Studies have shown that there is difficulty in processing rhythm in speech & music [2]
  - Also limited phonological awareness with rhyming, syllable deleting, segmentation and blending [3]
  - General lack of confidence when speaking
Music Cognition Lab Participants

- Identification of SLI:
  - Often identified by parents and/or teachers
  - There are numerous identification tools but they all focus on grammar and verb usage
- Potential subjects are found from pediatric speech clinics, flyers, and word of mouth
- How are subjects chosen for the study?
  - Potential subjects have screening visits to quantify language skills
  - Occurs by administering the SPELT-3 exam
  - This data excludes late talkers and untrue SLI
Manifestation of SLI- Nuclear Synchrony
Manifestation of SLI- Global Synchrony
Design Components

- **MATLAB program:**
  - Collect and analyze speech and metronome tracks
  - Utilization of toolbox functions and circular statistics (*PsychoPhysics* toolbox, Gstreamer)
  - Feedback and user interface to assess patient rhythm consistency and accuracy

- **Data analysis program must be compatible with:**
  - Various computer operating systems
  - A microphone (SM 58)
  - Headphones (any brand)
  - External Soundcard (Scarlett 2i2 system)

- **The design of the study will:**
  - Determine the rhythm baseline by sampling a population of individuals with normal speech development
  - Longitudinally assess impact of musical training on speech rhythm therapy
Soundcard Application working diagram

Scarlett 2i2 Soundcard

Input 1

Input 2 - The recording of the patient
Design Components: MATLAB Program

I. Load data into MATLAB

II. Filter the signal
   A. Take envelope of raw data: abs(hilbert())
   B. Butterworth lowpass filter: butter

III. Locate speech peaks
   A. [pks, loc] = findpeaks(data) returns peak amplitude and index
   B. for loop converts indices to time
   C. for loop runs through the vector of the location of peaks converted to time
      1. if statement locates time points within a specific, predetermined division of time.
      2. The maximum peak amplitude is found within the time division using an if statement. This value and its associated time value are saved to a new vectors.
      3. The process is repeated for the next time division.
   D. findpeaks locates absolute speech peak
Design Components: MATLAB Program

IV. Eliminate multiple points found on same speech peak
   A. for loop runs through all peak locations. Two subsequent peak locations are looked at at a time.
      1. if the two peak locations are spaced far enough in time (>=0.2s), both are valid peaks and saved to a new array. If not, only the first peak is saved to the final array.

V. Locate speech beats
   B. resample filtered data to reduce array size
   C. interpolate peak location and amplitude data to same size as resampled data
   D. for loop runs through resampled data
      1. for loop calculates 60% of each speech peak
         a) find all values in the resampled array for each 60% value
         b) for loop to compare indices found with the specific speech peak location. if the 60% value found is the last value found before the location of the associated speech peak, it is the speech beat associated with that peak. 60% indices and associated amplitudes are saved to a new array.
VI. Nuclear Synchrony
   A. locate the first, second, and third syllables of every phrase (ex: `syllable1 = t_60(1:3:end);`)
   B. `for` loop to find the difference in time between first and second syllables of every phase and first syllables of subsequent phrases
   C. `phase = (difference between first and second syllables)/(difference in time between first syllables)`
   D. Nuclear synchrony score = `mean` of phase values
   E. `circ_r`: mean resultant vector length

VII. Global Synchrony
   A. `for` loop separates metronome beats into two vectors: first and second beats
   B. `for` loop calculates the time difference between the first syllable and first metronome beat and the third syllable and second metronome beat for each phrase
      a. `if` both time differences are less than 0.666 seconds (one metronome beat), the phase is calculated
      C. `phase = (time difference)/0.666`; Global synchrony score = `mean` of phase values
   D. `circ_r`: mean resultant vector length
Progress: Hand Adjustments

Metronome beat vs Speech beat
Data Summary

- Elementary aged children considered to have good & normal speech
- It has been scheduled for us to collect more data in the upcoming weeks
  - 2-3 children with normal speech
  - 1 child with SLI
Pilot Study– “Bad for a game”

- Nuclear Synchrony=0.88282  
- Global 1st Syllable=0.93029  
- Global 3rd Syllable=0.9469  
- Global Average=0.938595
Trial- “Bad for a Game”

- Nuclear Synchrony=0.986405
- Global 1st Syllable=1.00
- Global 3rd Syllable=1.00
- Global Average=1.00
Trial- “Bad for a Game”
Temporary Setup for Analysis vs. Design Day Setup

- Recorded using FocusRite sound card
- Metronome played & speech recorded through Audio Live Lite
- Metronome and speech files were trimmed and exported as .wav files separately
- Using Simulink the .wav files were called and converted into MATLAB variables
- Analysis of metronome and speech workspace variables

- Recorded using FocusRite sound card
- Metronome played & speech recorded into MATLAB
- Analysis of metronome and speech workspace variables
Progress: Soundcard

- The Soundcard, using MATLAB code, now simultaneously plays the metronome while recording speech
Demonstration

- We are going to play a metronome for you, through headphones, using the soundcard
- While listening to the metronome we will say the phrase “Bad for a game” two times with you
- Then you will continue to say “Bad for a game” to the metronome on your own for 10 times
Next Steps

- Collect data in the upcoming trials for children both with and without SLI
- Continue to work on perfecting playing the metronome with the sound card
- Further improve consistency (improve ease of hand adjustments, etc.)
- Further investigate why our circular statistic output values are so high (and global synchrony code)
- Work with the Music and Cognition Lab to agree upon an appropriate metronome frequency
Questions & Comments
Resources

