Oral Presentation #5
Clinical Analysis of Speech Rhythms in Language Development using MATLAB

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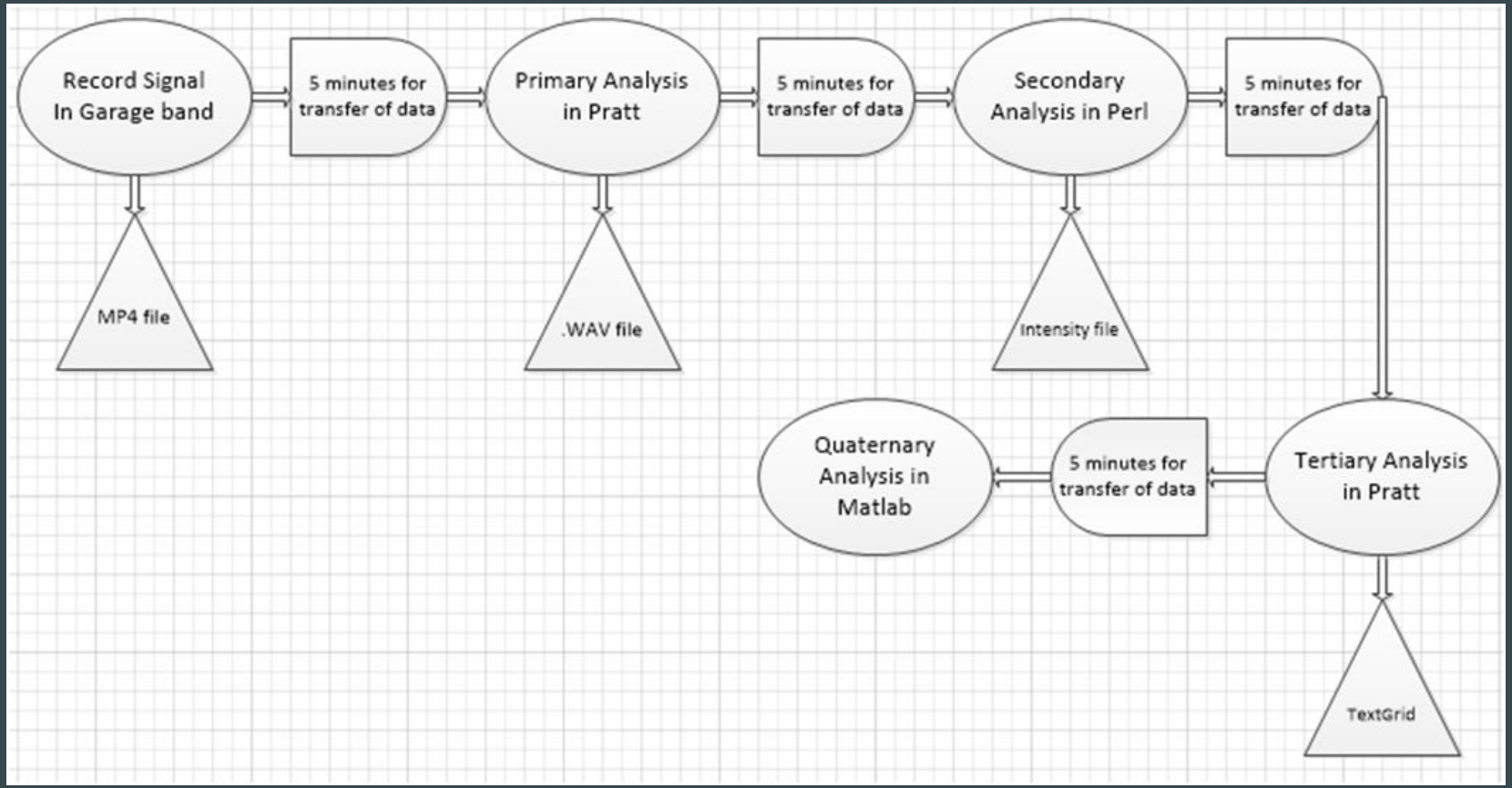
Problem Statement

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


Record Signal In Garage band
5 minutes for transfer of data
Primary Analysis in Pratt
5 minutes for transfer of data
Secondary Analysis in Perl
5 minutes for transfer of data
MP4 file
.WAV file
Intensity file
Quaternary Analysis in Matlab
5 minutes for transfer of data
Tertiary Analysis in Pratt
TextGrid

Needs Assessment

- Must:
  - **Detect the rhythm of the English language.**
  - Detect the rhythm of musical metronomes.
  - Compare rhythms of English language and music.
- **Data** collected from instrument **should be stored** for analysis and future retrieval.
- Design must **not exceed NIH grant budget.**
- Instrument **must be safe**, **physically compatible** with children, and **comfortable**.
- Design must allow for **variability between patient speech** and disorders.
- Lab setting must induce positive reinforcement for child compliance.
- Must be **compatible** with data files of past research.

Updated Needs Assessment

- 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

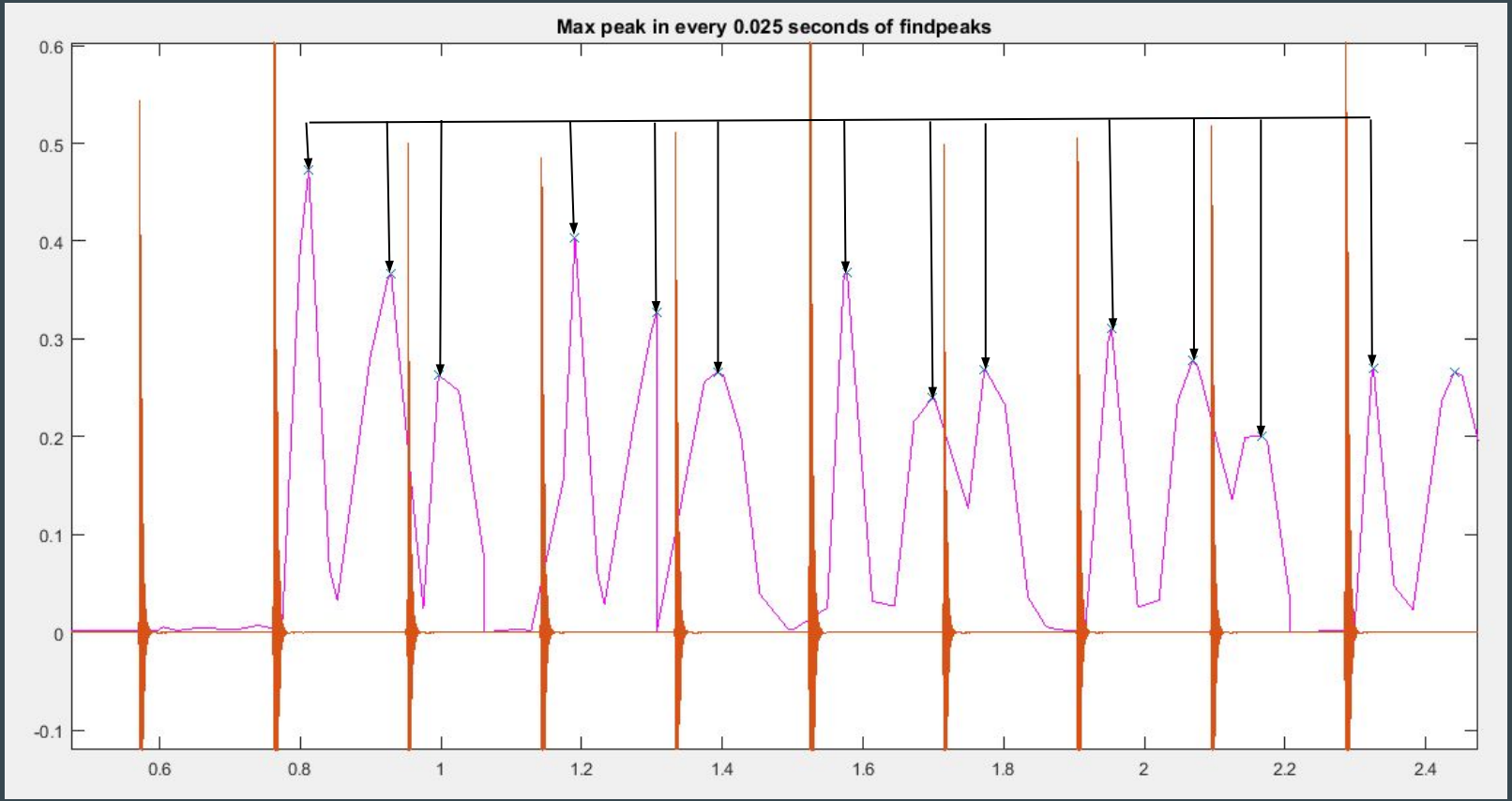
Specific Language Impairment

- 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

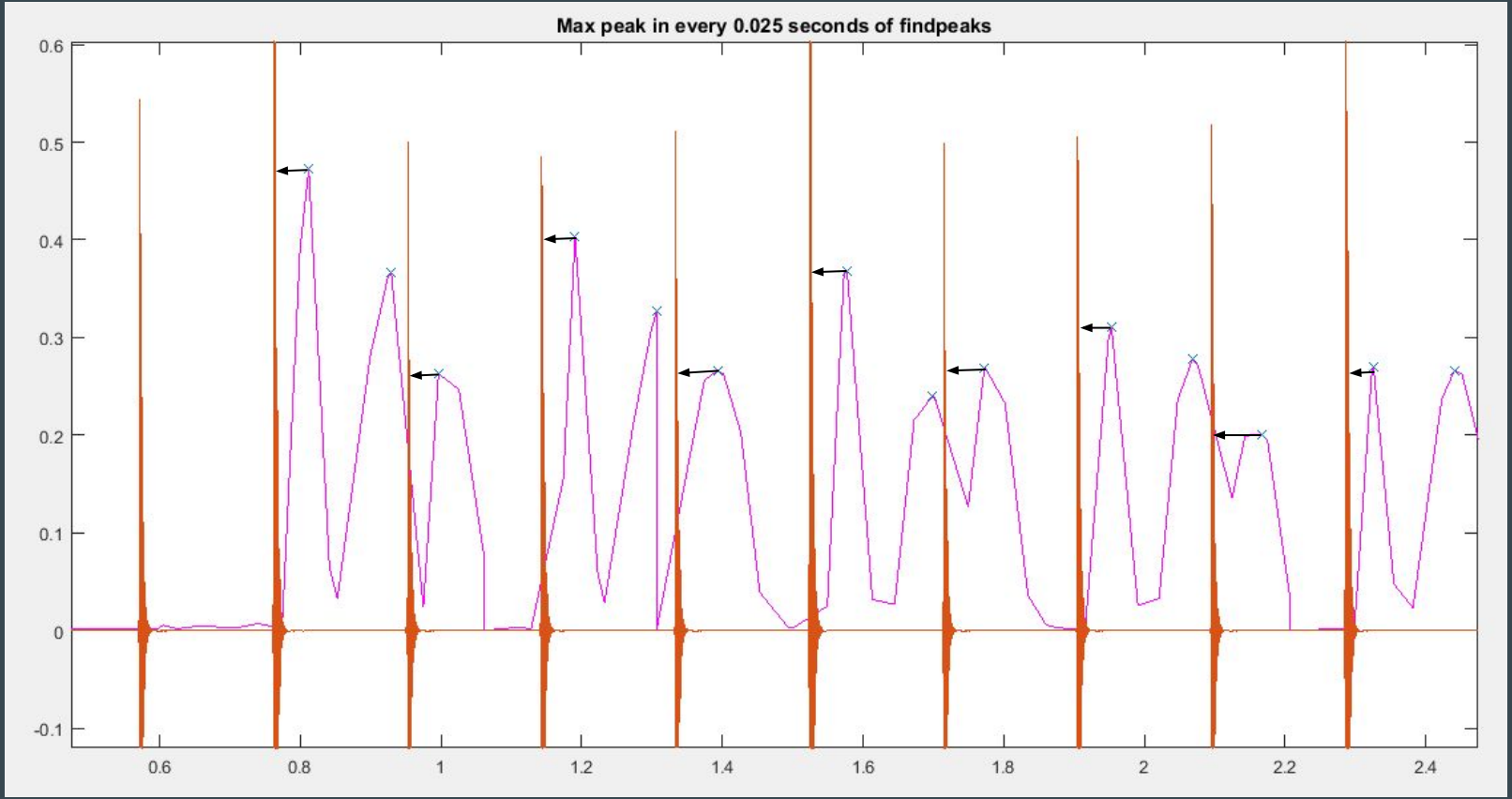
Music Cognition Lab Participants

- 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

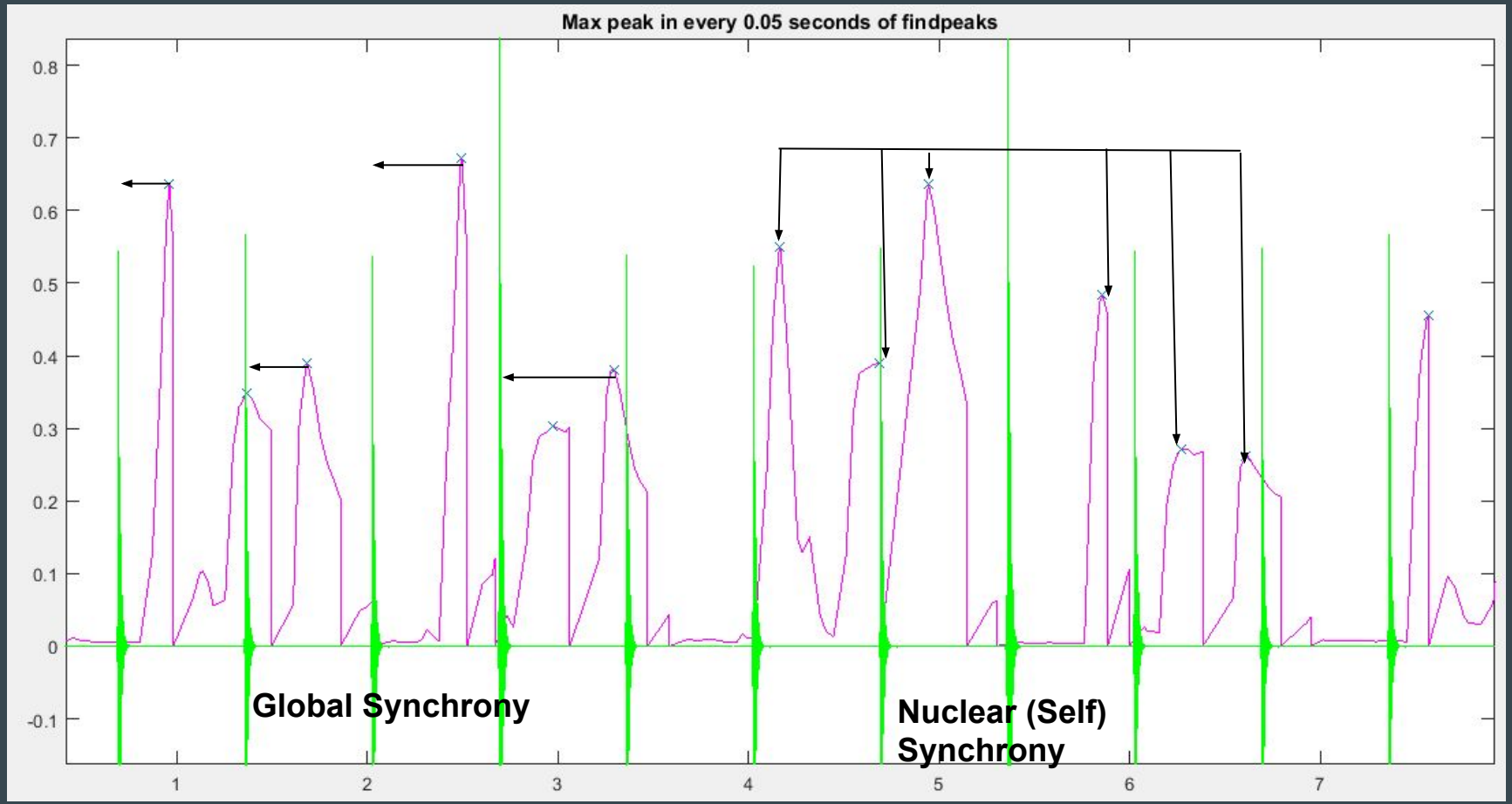
Manifestation of SLI- Self Synchrony



Manifestation of SLI- Global Synchrony



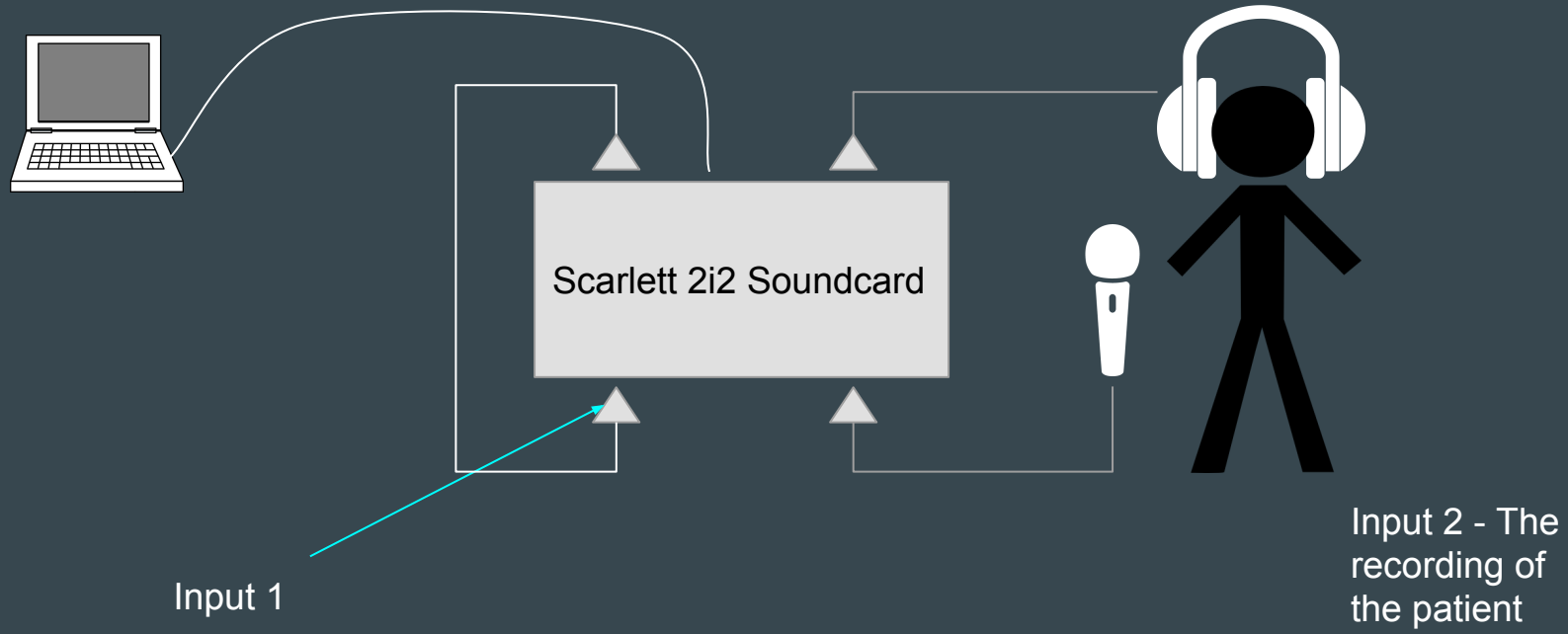
Example of Poor Synchrony



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



Design Component: Metronome & Amplitude

- 90 BPM was found to be “comfortable”
  - Through previous investigation by the Music Cognition Lab
  - Participants were instructed to speak in time with multiple different metronome speeds. The 90 BPM track was found to be the easiest to speak along with, so the Music Cognition lab adopted the track in its various studies.
- Amplitude of speech peaks changes from person-to-person
  - The natural rhythm of phrases sometimes causes people to ‘fade off’ at the end

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

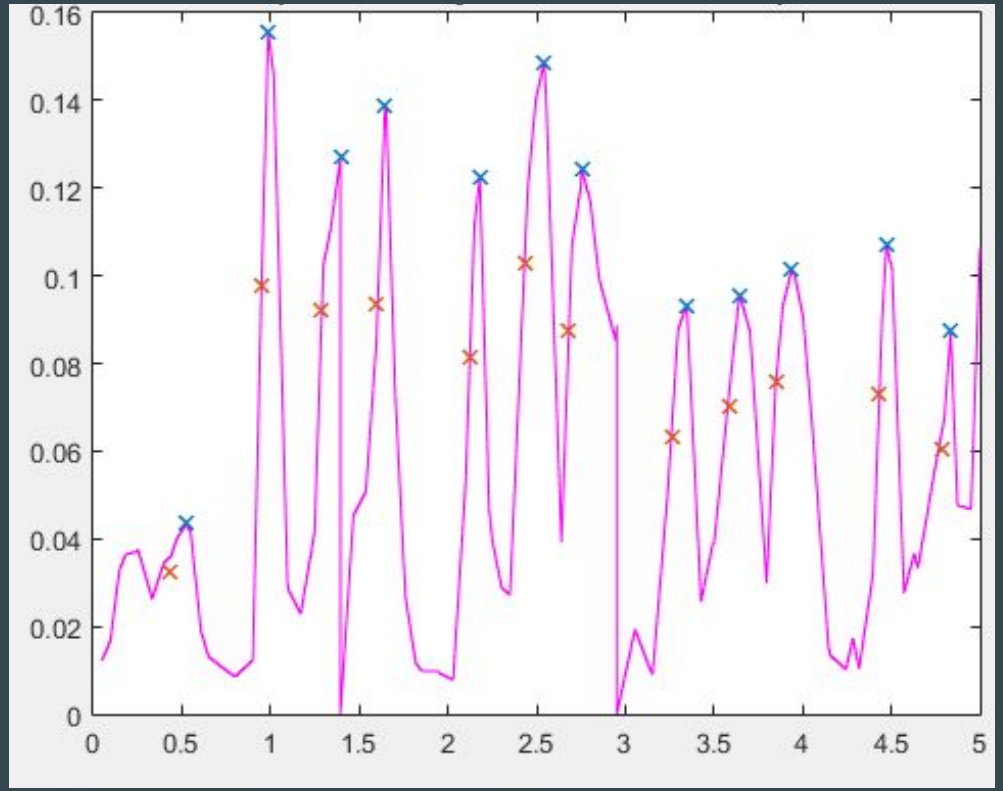
b) *for* loop to compare indices found with the specific speech peak location. *if* the 60% value found is the last value found before the location of the associated speech peak, it is the speech beat associated with that peak. 60% indices and associated amplitudes are saved to a new array.

Design Components: MATLAB Program

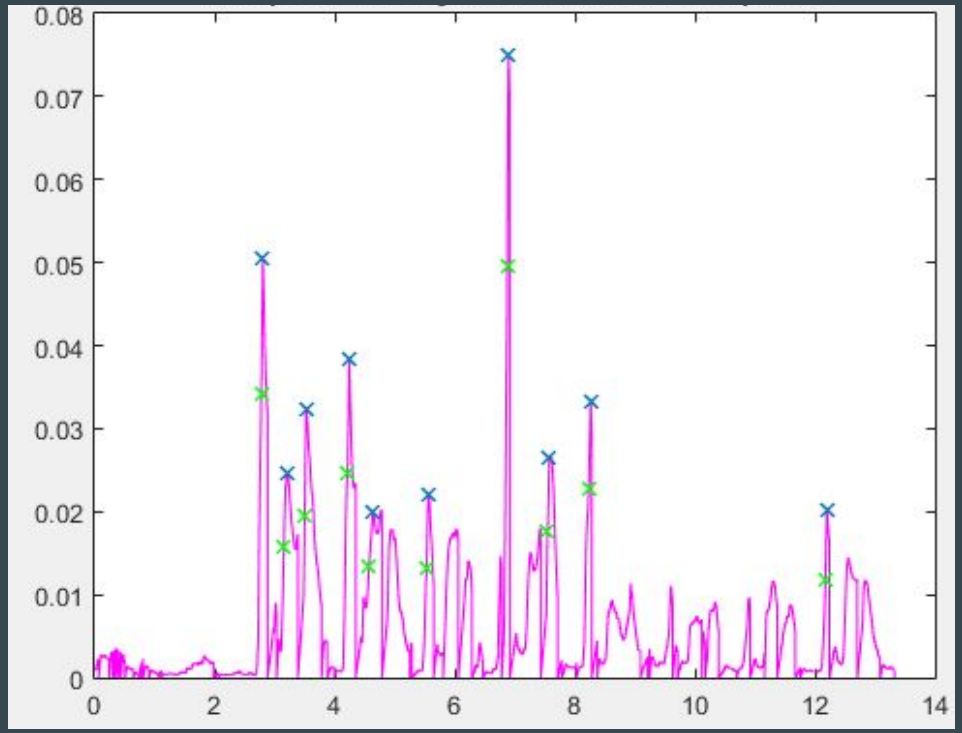
VI. Nuclear Synchrony
   A. locate the first, second, and third syllables of every phrase (ex: *syllable1 = t_60(1:3:end);*)
   B. *for* loop to find the difference in time between first and second syllables of every phase and first syllables of subsequent phrases
   C. phase = (difference between first and second syllables)/(difference in time between first syllables)
   D. Nuclear synchrony score = *mean* of phase values

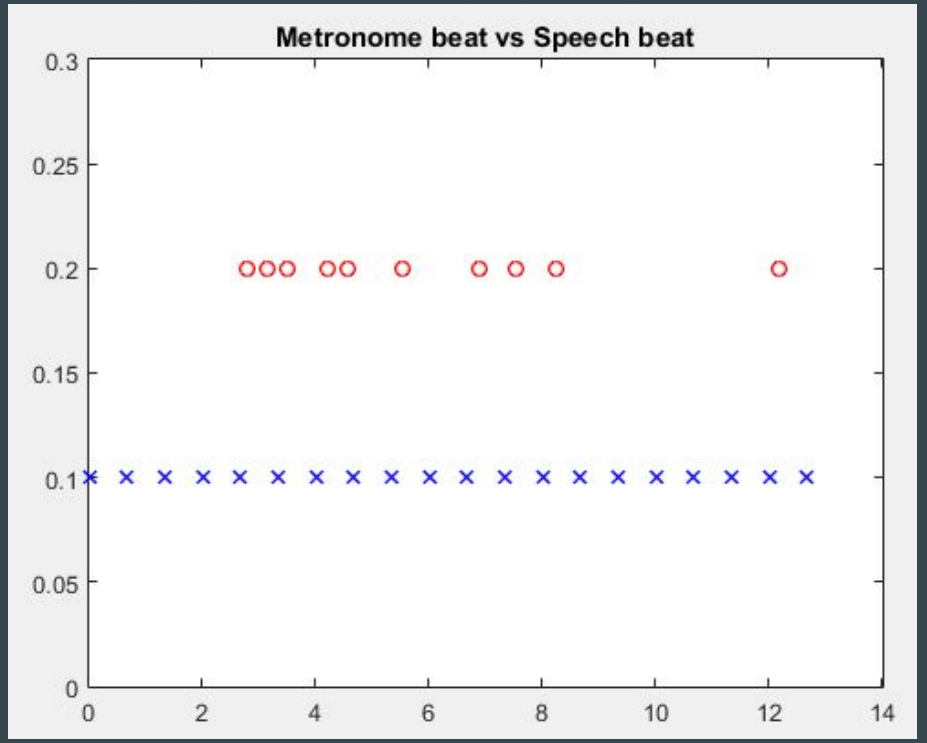
VII. Global Synchrony
   A. *for* loop separates metronome beats into two vectors: first and second beats
   B. *for* loop calculates the time difference between the first syllable and first metronome beat and the third syllable and second metronome beat for each phrase
      a. *if* both time differencs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

Continuation of Detecting of a Single Peak



Progress: Hand Adjustments





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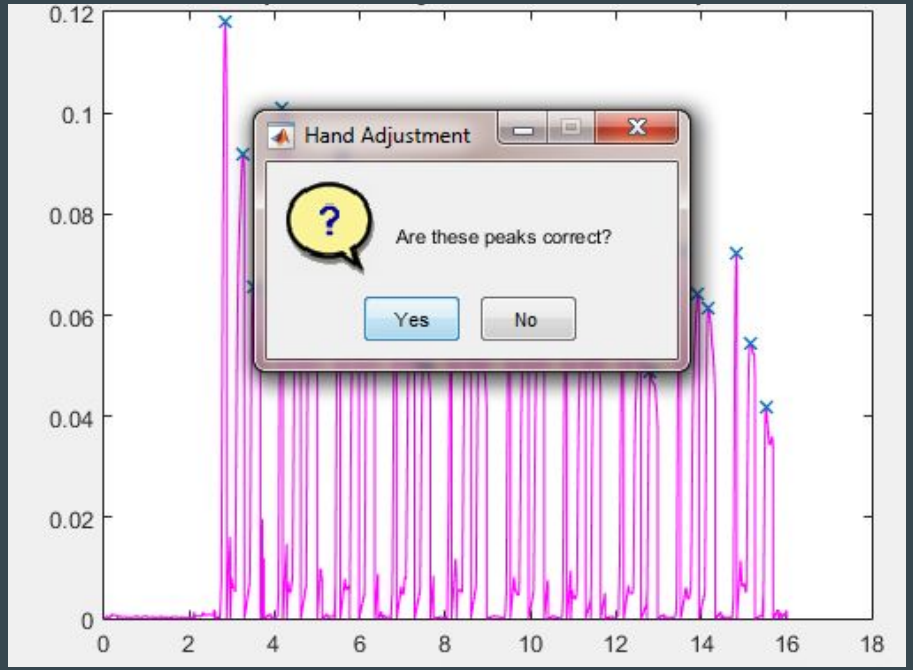
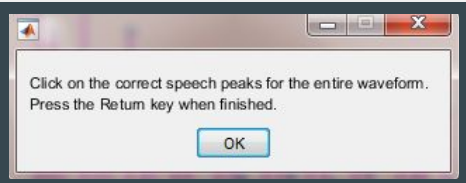
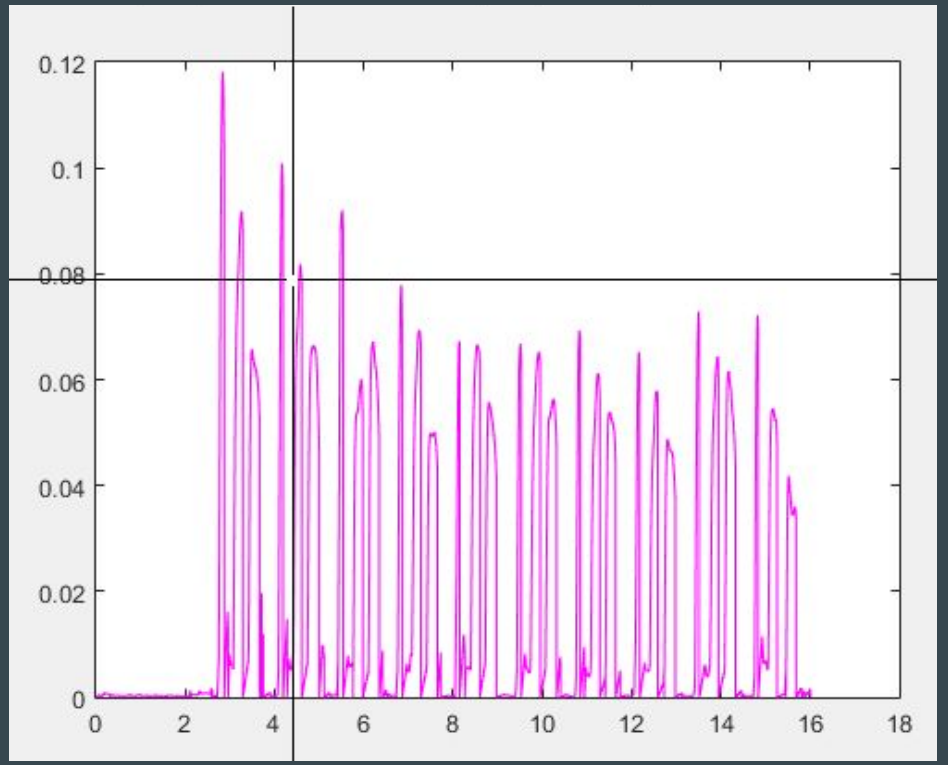
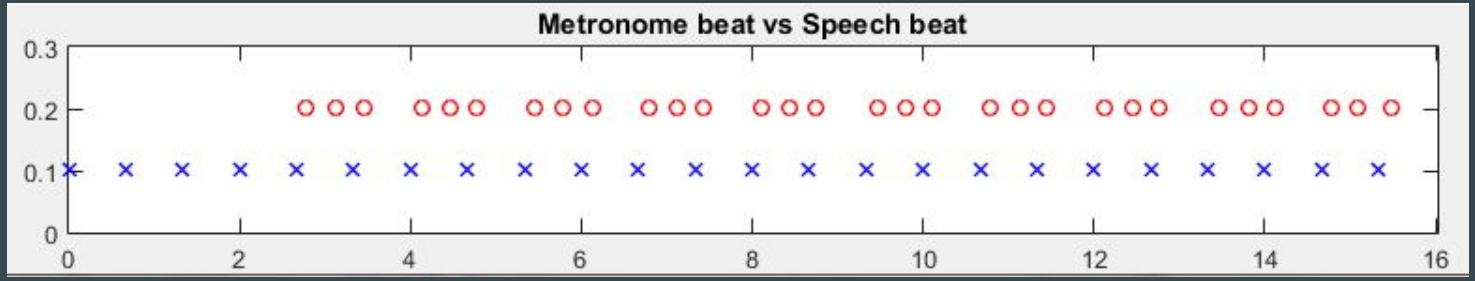
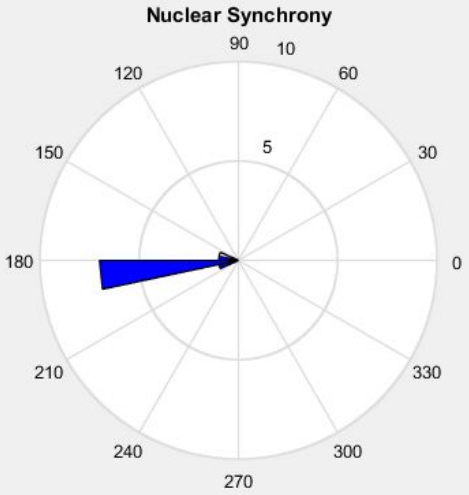


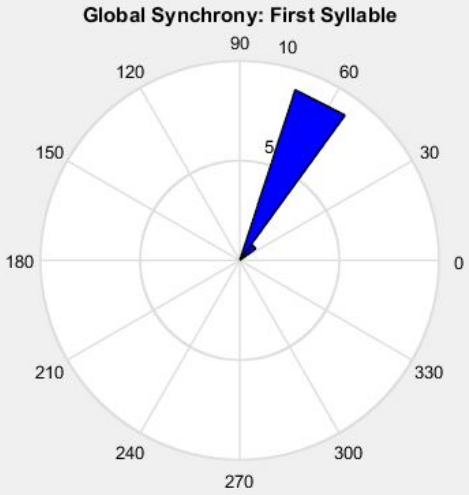




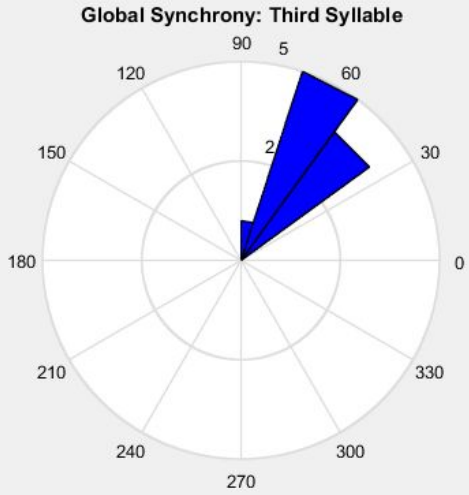




Nuclear Synchrony Score: 0.516273



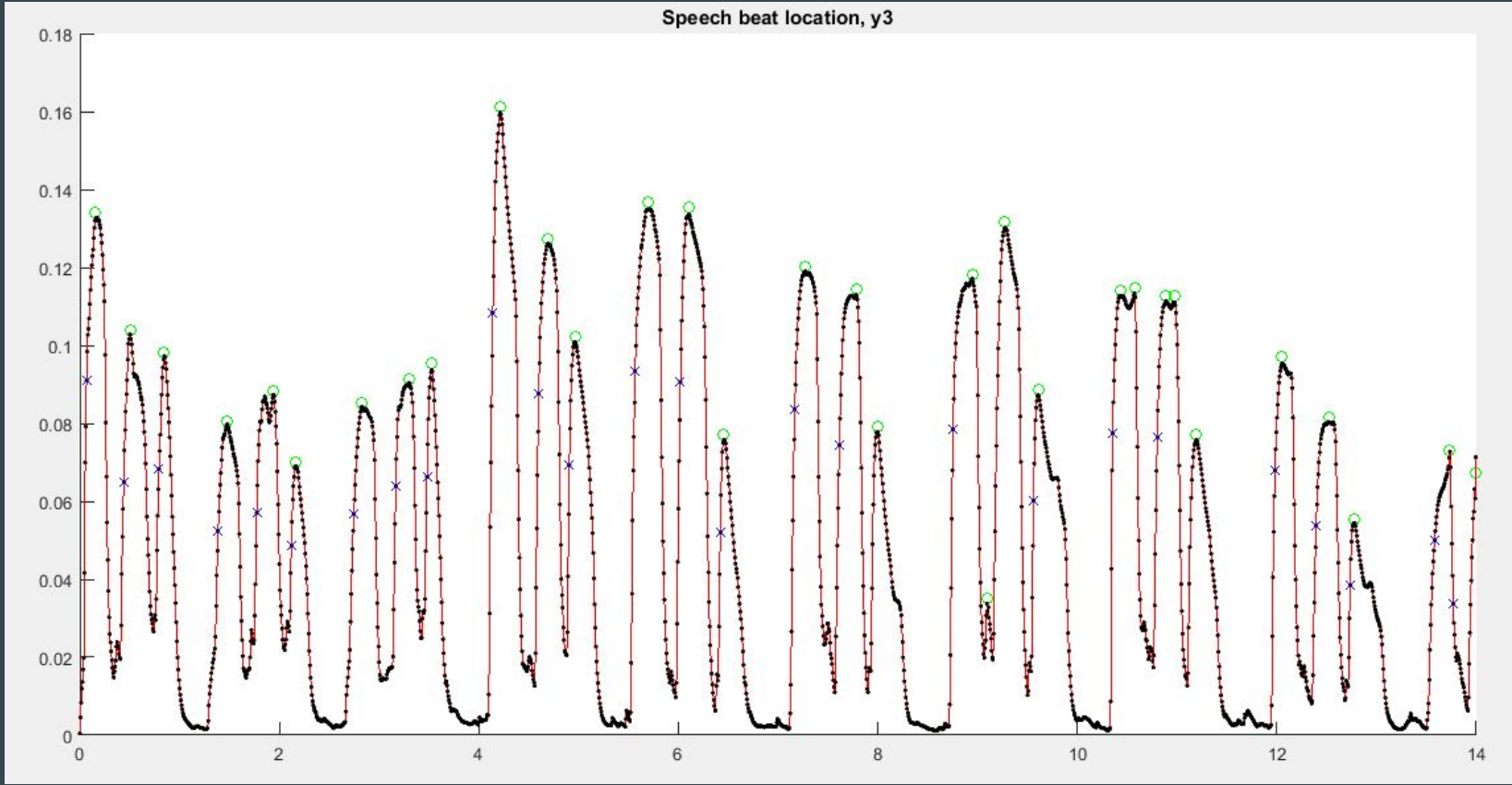
Global Synchrony Score, Beat 1: 0.180323



Global Synchrony Score, Beat 3: 0.165212

Global Synchrony Score, All: 0.172767

March 4th Pilot Study– “Bad for a game”



Next Steps

- Continue to work on metronome
- Further investigate and consult with Allison on what the circular statistics output should be
- Further improve consistency
- Order headphones

Questions & Comments

Resources

[1]http://www.nidcd.nih.gov/health/voice/pages/specific-language-impairment.aspx

[2]http://www.nuffieldfoundation.org/rhythmic-perception-music-and-language

[3]http://www.asha.org/PRPSpecificTopic.aspx?folderid=8589935327&section=Signs_and_Symptoms