# Clinical analysis of speech rhythms in language development using Matlab

Vanderbilt University, Department of Otolaryngology and School of Engineering

Ben Christ, Bachelors of Engineering, May 2016
Madeline Girard, Bachelors of Engineering, May 2016
Zeynep Sayar, Bachelors of Engineering, May 2016
Cathleen Trespasz, Bachelors of Engineering, May 2016

**Executive Summary**

Specific Language Impairment (SLI) is a language-disorder where patients exhibit reduced ability to form proper grammar and possess a narrower range of vocabulary. A recent study conducted by the Music Cognition Laboratory in the Department of Otolaryngology at Vanderbilt University has tested rhythmic abilities and expressive language in typically developing school-aged children with normal language development and SLI. The study has found a high correlation between rhythmic abilities and grammar skills which demonstrates the importance of rhythmic perception skills in language development.

Knowing that the ability to produce rhythmic speech, assessed by the ability to pronounce strong syllables in a sentence simultaneously with metronome beats, is beneficial in language development produces a currently unmet need for a speech data analysis method that can assess the quality of speech rhythm of an individual. The analysis of speech data in the Music Cognition Lab utilizes four different signal processing softwares (GarageBand, Perl, Pratt, Matlab) and currently takes 1-2 hours per patient to be completed. This is a very inefficient and ineffective process and is not practical for widespread and clinical applications. Therefore there is an immediate need for a streamlined speech data analysis method with the ability to simultaneously record speech rhythms and metronome beats, analyze and compare the audio data and provide live speech analysis feedback.

The solution we propose is a streamlined data analysis process that uses only MATLAB, as opposed to multiple data analysis programs. Data will directly be imported into MATLAB, processed, and exported to provide rapid feedback to the individual regarding his or her rhythm. Based on the rhythm assessment, the future direction of intervention or music therapy can be determined immediately by the clinician.

Our design solution has little-to-no competition due to the nature and need of the software. Within the technical detail of the data processing and analysis there is potential for variation, however, the design will collect and analyze data in the same manner regardless of the exact MATLAB code. The only existing competition is the current system used in the Music Cognition lab which involves the transfer of data between multiple different signal analysis tools. Although this system is inefficient, it does ensure that the analysis is able to be performed. Our design project will be beneficial and preferable to this method because it will simplify and automate the current process with no need for hard coding, therefore account for patient

variability, and will significantly reduce the overall time of the data analysis and eliminate the potential for human error while translating the data between different softwares.

Reimbursement strategies are not needed for the initial product since it will be purchased by the clinicians and not by the patients. The device will initially be used in isolated settings for clinical research, therefore FDA safety regulations are not applicable. However, the development of the device into a therapeutic method intended for speech pathology treatment, or expansion of the device application areas leading to usage in other clinical treatment, may lead to further FDA software approval.

The current buyer, user, and customer of device is Vanderbilt University Music Cognition Laboratory lead by Dr. Reyna Gordon. The device will not be initially commercialized, however potential future buyers include clinicians and research lab personnel who will use the program in their own research. Pricing will be determined both by value-based costing and cost-based pricing. Therefore both the cost of device hardware and, at later stages of implementation into clinical settings, the clinical value of the device will be taken into consideration. Pricing will also be comparable to the prices of future programming technologies and programs used for signal processing and analysis.

**Problem To Be Solved**

Preliminary research has been conducted that indicates a correlation exists between an individual's rhythmic capabilities and language development. In a pilot study conducted by the Gordon laboratory at Vanderbilt University Department of Otolaryngology, children were instructed to speak specific phrases in time with a metronome, and the correlation between grammar and rhythm for each child was found. However the data analysis process used in this study to analyze speech rhythm data consists of five different programs and takes up to 10-12 hours to be completed per patient, thus the method is inefficient and impractical to be used in a clinical setting.

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 of speech rhythm with a live quantitative feedback function regarding the quality of one's rhythmic abilities.

**Project Objective Statement**

To address the inefficiency of the current data acquisition and analysis, we plan to import data obtained from participants directly into MATLAB. Within MATLAB, complete analysis will be to be performed without having to change the data type or export data into a different program. This process will simplify the clinical analysis process, reduce data analysis time and potentially allow for live feedback of the participants' rhythmic abilities.

**Prototype and Documentation of the Final Design**

The final design will involve two main functionalities; data analysis and live analysis feedback. The prototype will include a Scarlett 2i2 Soundcard, microphone and headphones as the hardware components. Within the data analysis MATLAB Toolbox, Simulink and Scarlett Soundcard software will be used to supplement code and will compose the software components. Additionally the data analysis must be compatible with headphones and dual audio tracks; one of the audio tracks will be for the participants speech track and the other will be for the metronome. The live analysis feedback will involve an electronic screen interface that will be used to report the progress of the participant.

There is minimal risk analysis that needs to be performed for the final design; the final design instead just needs to accurately and precisely analyzes speech for clinical use.

**Proof of Functional and Successful Design**

To test our design, the code will first be run on data collected from a healthy population. Following success within this population, data from patients with speech pathologies will be tested. The first study to use our data analysis process will be a study conducted by Dr. Reyna Gordon involving children with language disorders.

The factors which determine the success of design are reduced data analysis duration compared to current method and the ability to provide live feedback of the individual's rhythm capabilities. Proof of successful functioning will be obtained from the comparison of healthy population speech analysis via our product and the current equivalent.

**Patentability and Anticipated Regulatory Pathway**

Currently no patents exist for a device or program used in the analysis of speech patterns and metronomes. Additionally, since this project falls into such a niche market there is little to no marketplace competition apart from home-grown analysis systems similar to the system currently used in the Gordon lab.

Due to the nature and use of this software, there is no expected FDA regulatory pathway as the FDA does not certify or validate software development tools. The software will be safe and unable to harm participants. The only physical interaction the device has with participants is through headphones; these are not a medical device. However, if the product were to be expanded beyond clinical research for therapeutic purposes, additional regulatory guidelines and pathways may need to be pursued and followed.

**Medicare and Medicaid Reimbursement**

The device is not expected to be reimbursable by Medicare, which provides health coverage if you are 65 or older or have a severe disability, nor Medicaid, which provides health coverage to patients who have very low incomes. The initial usage of the program will be analyzing data on children, thus Medicare age requirement is not met. Furthermore, the device and program will be purchased by clinical researchers and healthcare professionals and be used in research and data analysis, thus the patients will not be buying the device, eliminating the need for the device to be reimbursable by Medicare/Medicaid.

**Estimated Manufacturing Costs**

Our product is composed of both hardware and software components. The hardware components of the device are Scarlett 2i2 Soundcard (147$), headphones (depends on the brand, the most appropriate brand is still being discussed), SM58 microphone (99$), and 2 external USB cords. The software component includes the Scarlett 2i2 Soundcard Software, MATLAB and Simulink. MATLAB and Simulink can either be purchased separately for a total of 3,250$ or the Academic Version of MATLAB can be purchased at a price of 500$ which has Simulink pre-installed [1].

**Citation (APA):**

[1] Pricing and Licensing. (2016). Retrieved February, 2016, from http://www.mathworks.com/pricing-licensing/index.html?intendeduse=comm

**Potential Market**

The short-term market for our design is the Music Cognition lab. Ideally, the preliminary versions of our design will be tested in a study in 2016. In the future, the data analysis process and possible accompanying device will be used in a clinical setting as a diagnostic tool for a patient's rhythmic abilities. Immediate feedback would indicate to the clinician what direction to take in musical intervention. Future buyers will most likely be clinical research laboratories

specifically doing research concerning speech pathologies, and require signal processing, analysis and comparison of acquired data to different signal data sets. Following future advancements  in the research and device, adequate pricing will be modeled after competitor programming technologies and programs used for signal processing and analysis, the uniqueness and special features of the product will be taken into account.