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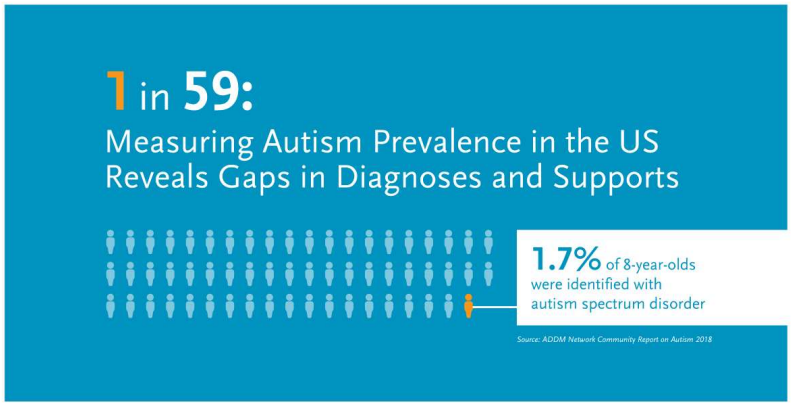
Early Language Assistance Therapy (ELAT) Robot for Children with Autism Spectrum Disorder

Miguel Esteban, Yu-chun (Eugene) Hsiao, Jonathan Ko, Myles Lewis, Remi Shittu, Andrew Yoon, Maurie Zhangs

Problem



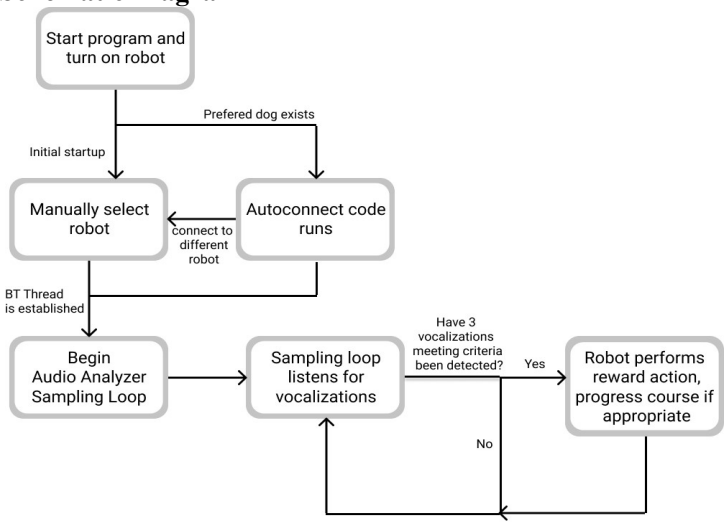
Source: https://www.cdc.gov/ncbddd/autism/data.html

- Approximately two-thirds of children with ASD will eventually have significant cognitive impairments.[1]
- Of the children affected by ASD, 30% - 40% of the children will remain nonverbal into adulthood.[2]
- Current speech therapy is dependent on visits with Speech Language Pathologists (SLPs), however, SLPS are not always accessible or affordable
- There is a need for a more cost and time effective therapy

Solutions

- Merged WowWee's CHiP Robot Software Development Kit (SDK) and audio analyzer java script by incorporating sampling, High Pass Filters (HPE), and various UI methods
- Machine learning methodology was implement to develop an automatic speech recognition (ASR) algorithm of verbalization attempts of children
- The product is able to detect vocalization and provide rewards through the robot, while distinguishing between adult and child, and will reward child vocalization

Schematic Diagram



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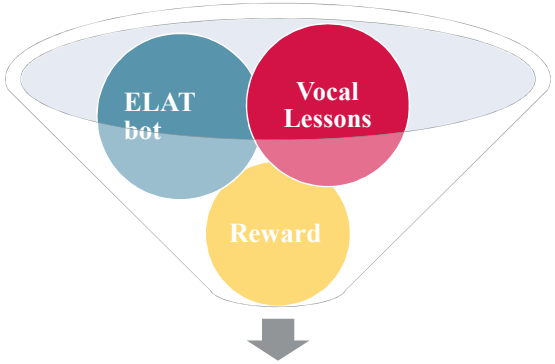
Background

- Because of the amount of children that remain nonverbal, the American Academy of Pediatrics (AAP) recommends that all children are screened for ASD, and that they immediately start intensive treatment if diagnosed with ASD.[3]
- In addition to the prevalence of this disorder in the US population, the cost of caring for children with autism spectrum disorder ranges from $11.5 billion to $60.9 billion.[4]
- Expensive cost of care leads to children unable to receive proper care needed to develop established verbal communication skills
- Families of newly diagnosed children face waitlists for therapy during critical early child development

Objectives

- ELAT's long-term goal is to develop a multi-faced tool that can assist and supplement traditional speech and language therapy for children with ASD.
- ELAT's short-term goals are developing a system that can:
  - *Develop a software to detect vocalizations, calculate a percent similarity value and adapt*
  - *Integrate the developed software into an affordable robot*

Summary of Results



Improved Expressive Speech

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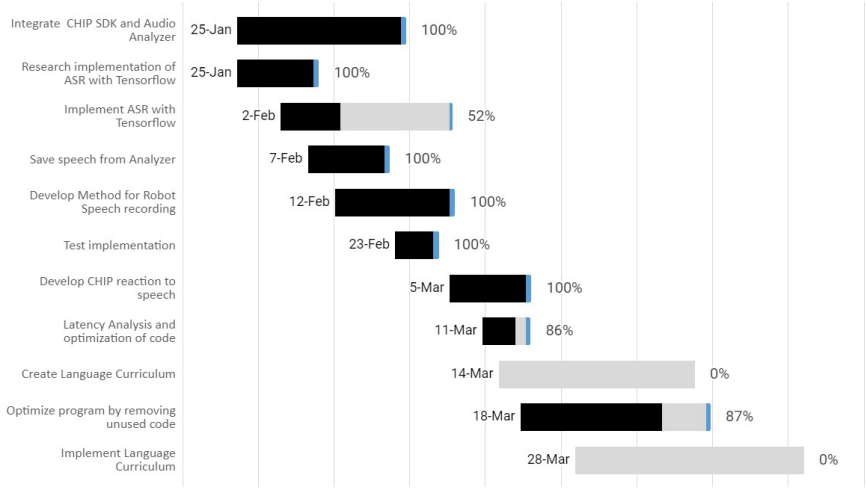
Programming methods

- Version control
  - Use of git as version control software, and github page as means of compiling code from all group members
- Merging two pre-existing pieces of software
  - Merged CHIP sdk and audio analyzer by incorporating sampling, fft, and various UI methods into the CHIP base sdk
- Write Bluetooth auto connect function
  - Save user preferences for preferred chip robot and allow user input to allow for auto connect
  - Implement observer pattern to recognize present chip robots

Programming methods

- Breaking down the Audio Analyzer
  - Takes chunks of vocal data, 64ms long, and performs fft on that chunk
  - Calculates spectral density of the sample to detect vocalization by analyzing three resonant peaks above 20dB above the mean
- Applied high pass filter to prevent analyzer from detecting a vocalization adult speech

Programming progress



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Automatic Speech Recognition Algorithm (ASR)

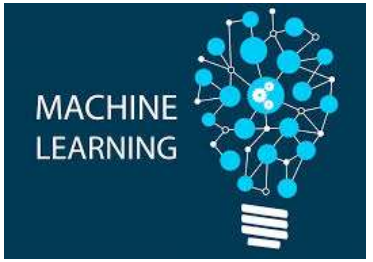
- Used a machine learning approach
- Developed an algorithm to recognize juvenile words & vocalizations
- Trained the algorithm on 3 datasets to ensure a powerful prediction
  - VCTK, LibriSpeech, and TEDlium

Testing the ASR

- Algorithm was also tested on a dataset of 5 words (Ball, Daddy, Jeep, No, Teapot)
- This dataset includes several recordings of vocalization from autistic individuals
- Each recording is associated with a quality score, a number out of 100. (Standard Score)

Vocalization Grading System:

- The algorithm uses a numerical grading system to assess the spelling of the ASR output
- The algorithm checks the character-based spelling of the ASR output against the actual spelling of the test word



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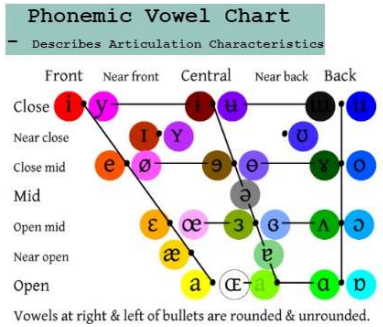
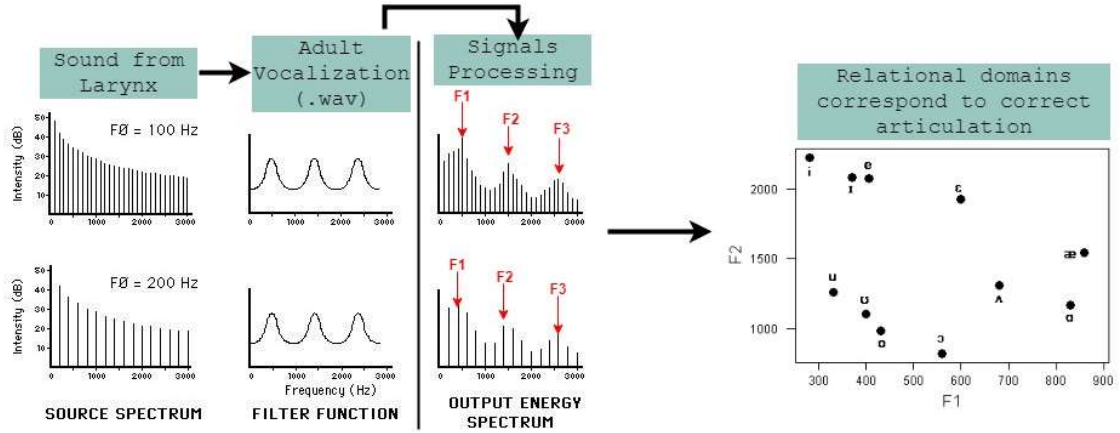
Linguistics Basis





- Studies on Adult Phonemic Vowel Vocalizations revealed that formants described physical articulation.
- This portion of the project addressed whether this could be said for child vocalizations.

DSP to Assess Child Vowel Space

- FmapsChild.m - Wrote MATLAB program to test analysis method.
- Considered whole words, not phonemic sounds.
- Input: Word Sound Directories with .wav files of vocalizations *Daddy*, *Jeep*, *Ball*, and *No*.
- Processed only vocalizations of children ages 2 – 5 years old.
- Identify Local Peaks within the Power Spectral Density of each .wav signal
- F1 Range: 200 – 800 Hz.
- F2 Range: 800 – 1800 Hz.
- F3 Range: 1800 – 3500 Hz.
- Output: 3D & 2D Scatter Plots – Comparing formant estimation relationships for all word vocalizations.

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Topic

- Audio Analyzer Software detects vocalization
- CHiP SDK commands robot
- Testing Merged Product under various conditions

Topic

- The product administers reward upon appropriate vocal detection
- Able to distinguish between various conditions
- Able to distinguish between adult and child vocalizations

Trial 1 (No Stimulus 0 db)		
Person	Stimulus	Response
Male	No stimulus	0
Male	No stimulus	0
Female	No stimulus	0
Male	No stimulus	0
Female	No stimulus	0

Trial 4 (Stimulus) Regular Speaking Voice		
Person	Stimulus	Response
Male	Speaking	1
Male	Speaking	1
Female	Speaking	1
Male	Speaking	1
Female	Speaking	1

Trial 2 (Whisper <20db)		
Person	Stimulus	Response
Male	Whisper	0
Male	Whisper	0
Female	Whisper	0
Male	Whisper	0
Female	Whisper	0

Trial 5 (Stimulus) Speaking Voice at ~5ft		
Person	Stimulus	Response
Male	Shouting	1
Male	Shouting	1
Female	Shouting	1
Male	Shouting	1
Female	Shouting	1

Trial 3 (Background Noise)		
Person	Stimulus	Response
Male	Table Hit	0
Male	Table Hit	0
Female	Table Hit	0
Male	Table Hit	0
Female	Table Hit	0

Trial 6 (Trial w/ Filter)		
Person	Stimulus	Response
Male	High Frequency	1
Male	High Frequency	1
Female	High Frequency	1
Male	High Frequency	1
Female	High Frequency	1

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Trials Using pre-Recorded Vocalizations for the word "teapot"			
File #	Standard Rating	ASR output	Algorithm score
File #1	.09	ol	0
File #2	.2	twot ine	0.1667
File #3	.25	wal one	0
File #4	.25	e o	0
File #5	.3	pal toe	0.1667
File #6	1	tee pat	0.667
File #7	1	tee pup	0.5
File #8	1	hee poke	0.5
File #9	1	tea paut	0.667
File #10	1	ehy poch	0.33
File #11	1	inty match	0
File #12	1	heet hat	0.1667

- The algorithm is able to return a phonetic character-based spelling of the input .wav file
- The scoring algorithm calculated a number to assess how correct the phonetic spelling was to the test word.

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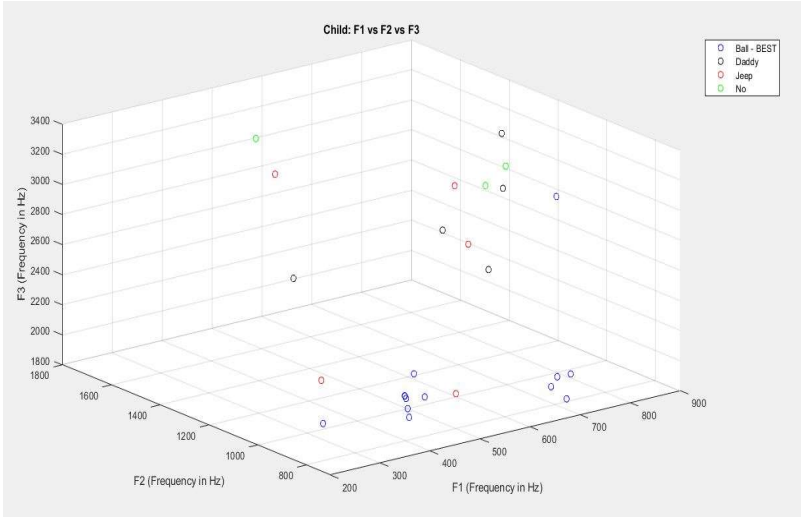
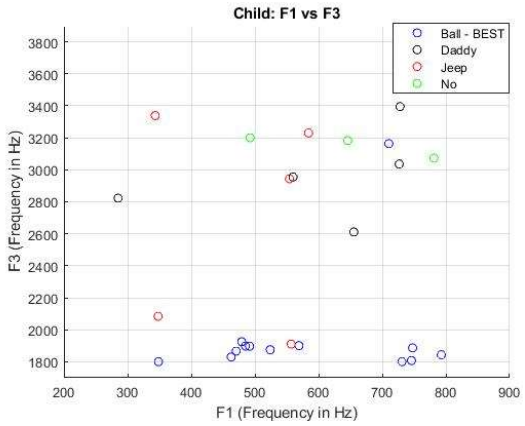
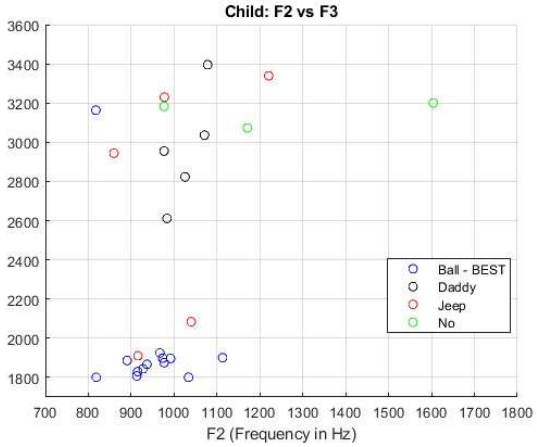
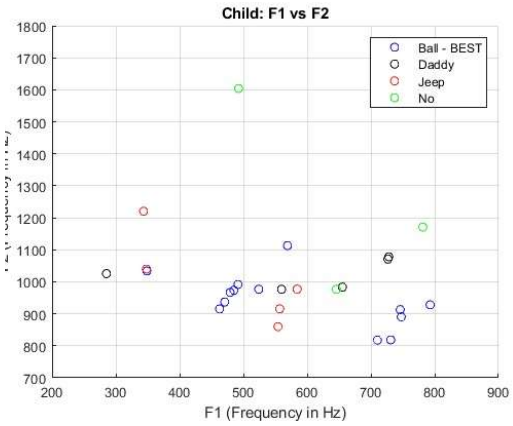
- Studying vowel formants of child vocalizations did not reveal clear domains for vowel sounds.
- Many variables impact speech perception.
- Limited data set and limited details on the data set limited analysis possible during the length of the project.
- **Future iterations will need to consider more speaker-specific information.**
- Intonational Information
- Average formant values for a given speaker, for the same sounds.
- Indexical Information
- etc.









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Next Steps

- We would also like to integrate our improved speech recognition and DSP with the already developed app for better speech processing than is currently available
- We would also like to add a language curriculum, expanding the vocabulary for the robot, and adding elements that become more difficult over time, encouraging the child to continue to improve
- We would like to integrate our ELAT software with ImagiRation's current Recessive Language called MITA with hopes to improve a child's use of language
- We would also be continuously working on ELAT to better its interface and user experience
- With more feedback, we would send out application updates to provide the best for our users and customers.

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[4] Boat, Thomas F. "Clinical Characteristics of Autism Spectrum Disorder." Mental Disorders and Disabilities Among Low-Income Children., U.S. National Library of Medicine, 28 Oct. 2015, www.ncbi.nlm.nih.gov/books/NBK332891