EarGenie - A clinician-friendly fNIRs system to evaluate infant speech detection & discrimination

G. Balasubramanian[1,2] , J. Wunderlich[1,2] , D. Mao[1,2], L. McDonald[1], D. X. Gao[1,2], C. M. McKay[1,2]

[1] The Bionics Institute, 384-388 Albert St, East Melbourne VIC 3002, Australia, [2] Department of Medical Bionics, University of Melbourne, Parkville, VIC 3010, Australia.

* For more information, please email GBalasubrmanian@bionicsinstitute.org

THE UNIVERSITY OF MELBOURNE

Bionics Institute

Introduction

Infant Speech Detection & Discrimination

- Current methods of auditory testing cannot accurately test for speech discrimination which is crucial for language development.
- Hearing assessments for infants with auditory neuropathy (AN) are also not reliable.
- Our system, EarGenie (Fig. 1), is an end-to-end fNIRs (Functional Near Infra Red Spectroscopy) system that tests for detection and discrimination including for infants with AN.
- It can be used to evaluate hearing aid and Cochlear Implant (CI) programs due to its patient-friendly, non-invasive nature.
- Our custom analysis algorithm was developed and evaluated using NIRx sensor measurements across 4 regions of interest (ROI): left and right temporal and prefrontal regions.

EarGenie - Prototype build in progress

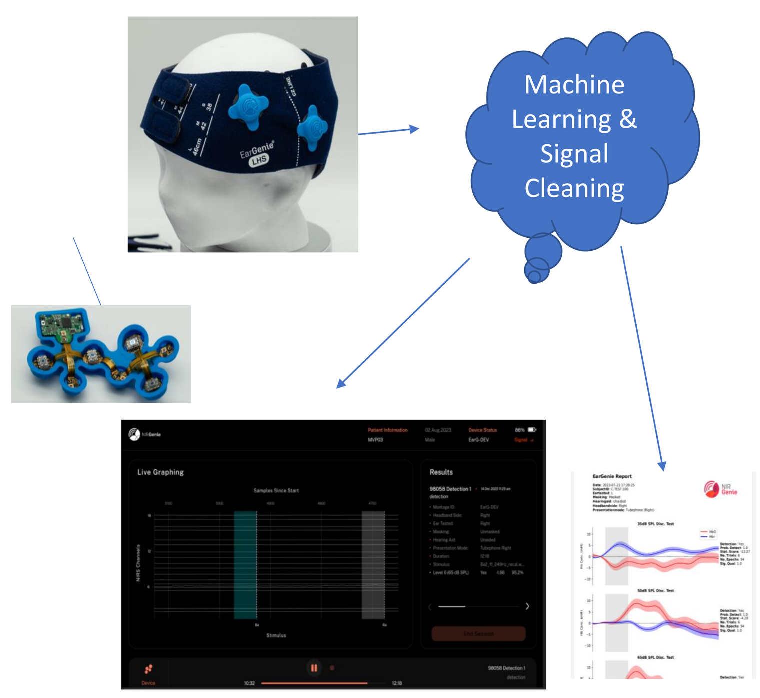

Fig. 1: Ear Genie System components

Method

Participants & Stimuli

- We show results for speech detection ("Ba" presented at 65 dB SPL) and discrimination using 3 different speech-token contrasts: Ba/Tea , Ba/Bee , Ba/Ga as well as performance across tokens presented at multiple intensities.
- Subjects were 34 infants with normal hearing aged between 2 and 20 months who were tested while asleep. The stimulus presentation protocol used is shown in Fig 2.
- Each 5.4 s stimuli block, was either 12 concatenated "Ba" tokens in the detection phase or alternating "Ba" and contrast token in the discrimination phase.

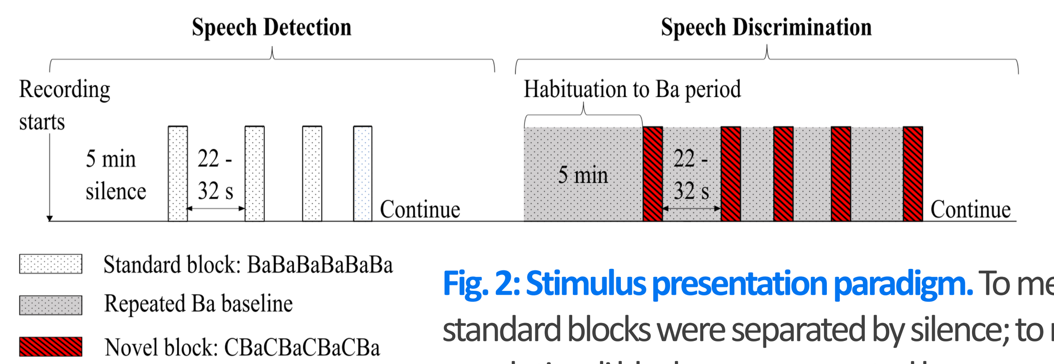

Fig. 2: Stimulus presentation paradigm. To measure speech detection, the standard blocks were separated by silence; to measure speech discrimination, the novel stimuli blocks were separated by a repeated Ba stimulus.

Data Pre-processing included:

- Conversion to optic density and removal of noisy channels and physiological noise using the Scalp Coupling Index (>0.75), Temporal Derivative Dispersion Repair and Bandpass Filter (0.01 – 0.25 Hz).
- Conversion to HbO and HbR signals by applying modified Beer Lambert law.
- Epoching and baseline correction of fNIRs signals between -3 and 27 s post stimulus onset. Control epochs were also gathered from the silence (detection) or non-silence baseline (discrimination).

Post-Processing:

- The EarGenie custom algorithm uses online processing. Hence data was processed in an incremental fashion, starting after 3 trials, and after each subsequent trial. The testing automatically stops the test for a token when it identifies a significant detection or discrimination.
- A stochastic process approximates epochs gathered in both control and post-stimulus conditions.
- Statistical tests are carried out to evaluate the similarity of control and stimulus epochs. The statistical tests are permuted by varying the controls to ensure the presence of a consistent response.
- A control vs. control test is executed to test for the possibility of a false positive. Additionally, separate testing was conducted with silent 0 dB trigger in a subset of subjects.

Results

We require our algorithm to show a significant result in at least 2 of the 4 ROIs to be considered a true detection or discrimination. Tables 1 and 2 show the number of infants out of 32 who showed significant results in different number of ROIs.

Table 1 - Speech Detection Sensitivity

# ROIs Detected out of 4	All 4 ROIs	3 ROIs	2 ROIs	1 ROIs	0 ROIs
# infants out of 32	21	9	1	1	0

- For detection (Table 1), 31 infants out of 32 showed detection in 2 or more ROIs (**97 % sensitivity**).

Table 2 – Speech Discrimination Sensitivity

# ROIs Detected out of 4	All 4 ROIs	3 ROIs	2 ROIs	1 ROIs	0 ROIs
Ba/Tea # infants out of 16	8	5	2	1	0
Ba/Bee # infants out of 26	15	5	3	1	2
Ba/Ga # infants out of 18	9	3	2	3	1

- For discrimination (Table 2), 15 infants of 16 showed Ba/Tea discrimination (**94 % sensitivity**).
- 23 infants out of 26 showed Ba/Bee discrimination (**88 % sensitivity**) .
- 14 infants out of 18 showed Ba/Ga discrimination (**78 % sensitivity**).

Table 3 - Speech Detection Sensitivity at soft intensity levels

# ROIs Detected out of 4	≥ 2 ROIs	< 2 ROIs
35 dB SPL # infants out of 6	6	0
45 – 50 dB SPL # infants out of 13	11	2

- For detection at soft intensity levels (Table 3), 6 infants out of 6 showed detection at 35 dB SPL in 2 or more ROIs (**100 % sensitivity**).
- 11 infants out of 13 showed detection at 45 - 50 dB SPL in 2 or more ROIs (**85 % sensitivity**).

Specificity

The control vs. control tests were conducted across all subjects and speech tokens to identify the probability of false positives. The probability of false positives is 5 %, i.e., **95% specificity.**

Test efficiency

A significant detection or discrimination response was identified by the algorithm within 5 trials (equivalent to 2.5 minutes following the control segment) in ~ 70 % of the cases described, which validates an online processing approach .

Conclusion

We have a robust algorithm to determine detection and discrimination of speech sounds by sleeping infants using fNIRs sensors. Furthermore, significant response detection was often obtained using less than 5 sound presentations, and at levels as low as 35 dB SPL. Further testing with the EarGenie hardware is set to commence shortly after bench testing success.

References:

[1] McKay et. al. A reliable, accurate, and clinic-friendly objective test of speech sound detection and discrimination in sleeping infants. (Psyarxiv)

[2] McDonald et. al. EarGenie, an innovative test to measure speech discrimination using functional near-infrared spectroscopy. J. Acoust. Soc. Am. 154, A33–A34 (2023)

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