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Brain Activation for Cochlear Implant Users: A Pilot fNIRS Study

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INTRODUCTION

- Cochlear implants (CIs) have become a widespread device for individuals with severe-to-profound sensorineural hearing loss (SNHL) to regain hearing ability. CIs have improved communication skills and quality of life for individuals with SNHL[1].
- However, the brain needs to adapt to this bionic device and relearn the function of hearing, especially for speech sounds. Because the auditory inputs through a CI are not the same as those heard by individuals with typical hearing, aural rehabilitation takes time.
- The goal of this study is to examine neural bases of speech perception in adult CI users using functional near-infrared spectroscopy (fNIRS).

MATERIALS & METHODS

- **Participants:** 2 adults with bilateral SNHL and CI(s) (1 female, native English speakers)

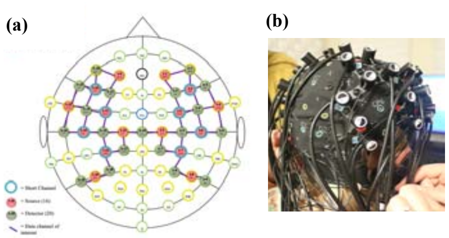

Figure [1]

Figure [1] (a) shows the montage of 16 sources represented by red circles and 20 detectors represented by blue circles, 8 short channels represented by blue circles, and 44 channels of interest represented by purple lines; (b) shows the design of the fNIRS cap while on a participant with blue tags for detectors and red tags for sources.

- **Procedure:** After positioning the cap, we calibrated the detectors and sources until all channels passed signal-to-noise ratio tests. We collected fNIRS data during two tasks. (i) Speech listening task: the participant hears speech samples recorded by audiology students; (ii) Resting task: the participant was told to be relaxed with eyes open, focusing on a white cross on the black screen.

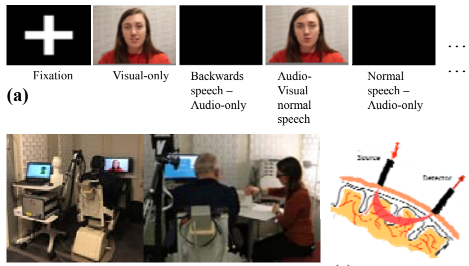

Figure [2]

Figure [2] (a) shows the speech listening task. There are five conditions including "cross", "audio-only – backwards speech (b-a-only)", "audio-visual normal speech (a-v)", "audio-only – normal speech (a-only)", "visual-only – no audio (v-only)". Each condition lasts 30 seconds. There are 7 "cross", 4 "v-only", 3 "b-a-only", 5 "a-v", and 3 "a-only" conditions randomly presented. The whole task lasts 630 seconds. (b) shows one participant doing the speech listening task when wearing a fNIRS cap and after fNIRS sessions, the participant also completed cognitive tests. (c) shows the principle of the light travel path (like a banana shape) from source to the detector.

- **fNIRS:** fNIRS monitors oxygenation changes in the brain by measuring changes in optical absorption[2] and can be used safely to detect brain functions in cochlear implant users.
- **fNIRS Data Processing**: We used nirsLAB to preprocess the fNIRS data including denoising, removing artifacts, filtering (band-pass: 0.01-0.2 Hz), and to compute hemodynamic states for the five conditions. The source-detector distance is 3 cm and the two wavelengths are 760 nm and 850 nm, and the guiding principle is the modified Beer-Lambert law[3].

RESULTS

The present study is still on-going. Here we presented the two participants (AC001, 72 years old female, AC002, 69 years old male). They both have bilaterally implanted cochlear implant devices. Due to limited sample size, we are not able to compute group statistics. The results are shown for each participant in Figure 3 and 4. We focused on the difference maps for the following six contrasts: (1) "a-v" > "a-only", (2) "a-v" > "v-only", (3) "b-a-only" > "cross", (4) "a-only" > "cross", (5) "b-a-only" > "a-only". The reason for picking these six contrasts is based on our interests of speech perception abilities in cochlear implant users.

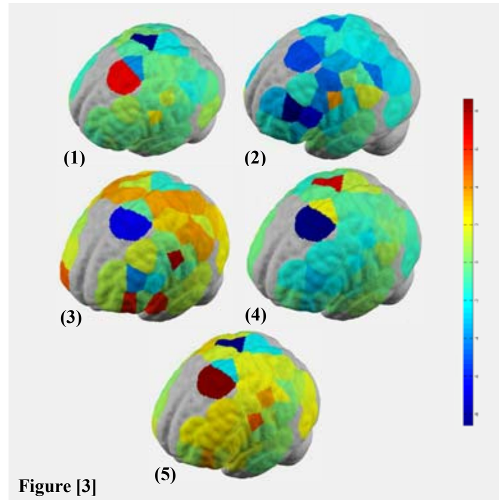

Figure [3]

Figure [3] (1) "a-v" > "a-only", (2) "a-v" > "v-only", (3) "b-a-only" > "cross", (4) "a-only" > "cross", (5) "b-a-only" > "a-only". Color-bar represents the t-value for the statistical test.

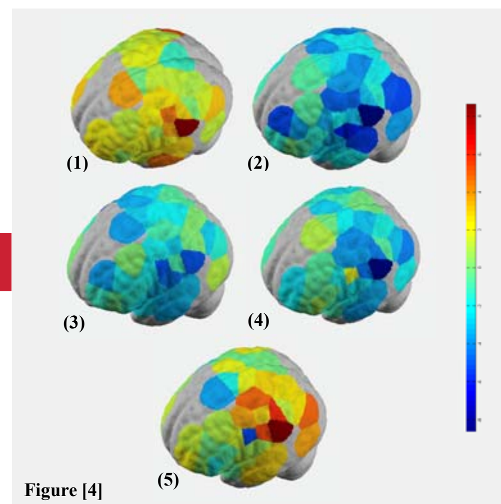

Figure [4]

Figure [4] (1) "a-v" > "a-only", (2) "a-v" > "v-only", (3) "b-a-only" > "cross", (4) "a-only" > "cross", (5) "b-a-only" > "a-only". Color-bar represents the t-value for the statistical test.

Contrast (1) tabs into the brain responses to visual cues. Contrast (2) identifies brain responses to auditory processing of speech sound. Contrast (3) examines brain regions involved in non-speech sound processing. Contrast (4) determines brain regions involved more in non-speech sounds versus speech sounds. Based on the pilot data, we found that there were big individual variances in the brain activation patterns (Figure 3, 4).

CONCLUSION

Our pilot study showed feasibility of fNIRS on studying brain activation in cochlear implant users during speech listening task. The differences of brain responses may help us understand the differences of speech perception abilities in CI users. But we need to collect more fNIRS data to draw reliable conclusions.

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