Gabriel Sobczak, MD

Resident - Indiana University

“fNIRS Evidence for Underlying Neural Mechanisms of Spatial Release from Masking in Single-Sided Deaf Cochlear Implant Listeners”

FELLOWSHIP GRANT 2020

Amount Awarded by AOS: $44,000

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PUBLICATIONS:

Cortical mechanisms of across-ear speech integration investigated using functional near-infrared spectroscopy (fNIRS). Sobczak GG, Zhou X, Moore LE, Bolt DM, Litovsky RY (2024). PLOS ONE 19(9): e0307158. https://doi.org/10.1371/journal.pone.0307158

RESEARCH SUMMARY:

This study aimed to identify potential neural signatures of across-ear speech integration. We presented sentence segments alternating between ears to participants, while measuring cortical activity using functional near-infrared spectroscopy (fNIRS). Cortical activation in each region of interest (Figure 1) was recorded using fNIRS while typical-hearing listeners were presented with 12 conditions (Figure 2). In a separate session, speech intelligibility scores were calculated for each of the 12 conditions. The study was motivated by evidence that people with hearing loss who are fitted with CIs show deficits in being able to integrate information across the two ears.

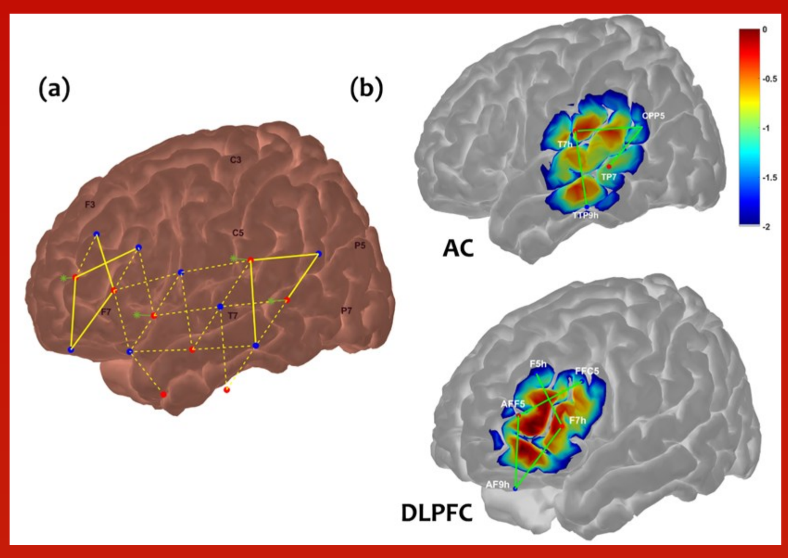

Figure 1. Illustration of fNIRS montage and cortical regions of interest. (a) fNIRS montage, showing sources (red dots), detectors (blue dots) and short-channel detectors (green asterisks). Yellow lines connecting a source and detector represent measurement channels. fNIRS montage was symmetric between the left and right hemisphere. (b) Selected channels comprising a priori ROIs, the auditory cortex (AC) and dorsolateral prefrontal cortex (DLPFC); ROIs are only shown on the left hemisphere for demonstration purposes. Colormap corresponds to sensitivity profiles for each ROI channel grouping, in units of log -10 mm-1.

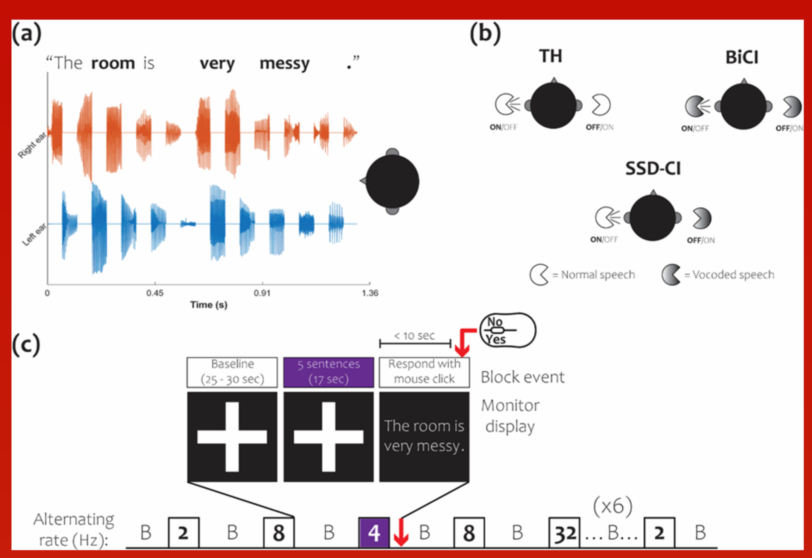

Figure 2: Alternating speech stimulus, speech conditions, and fNIRS data collection. (a) Spectrogram demonstrating an example non-degraded AuSTIN sentence, “The room is very messy ”, segmented and alternating between ears at 8 Hz. Additional alternation rates included 2, 4, and 32 Hz. (b) Organization of speech conditions: TH = non-degraded speech in both ears; SSD-CI = vocoded speech in right ear, non-degraded speech in left ear; BiCI = vocoded speech bilaterally. (c) Pseudorandom block design, with stimuli in 4 listening conditions (boxes); 4 alternating rates presented at one speech condition in random order during each data collection session.

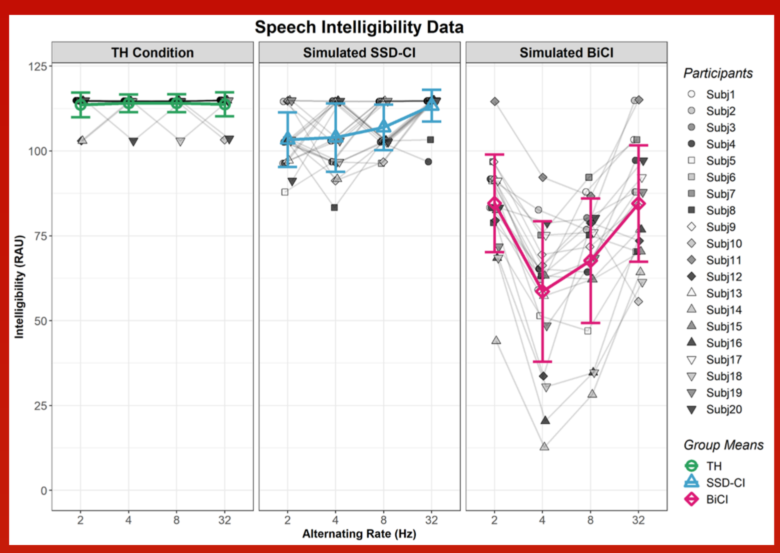

Figure 3: Participant-level speech intelligibility data in rationalized arcsine units (RAU), at all four alternating rates. Figure panels are separated by speech condition. Connecting lines between each participant’s datapoints are added to illustrate participant-level patterns across alternating rates. Group-mean speech intelligibility ± 1 standard deviation (SD) is superimposed on participant -level data. Speech intelligibility data were collected in a separate behavioral experiment without fNIRS recording.

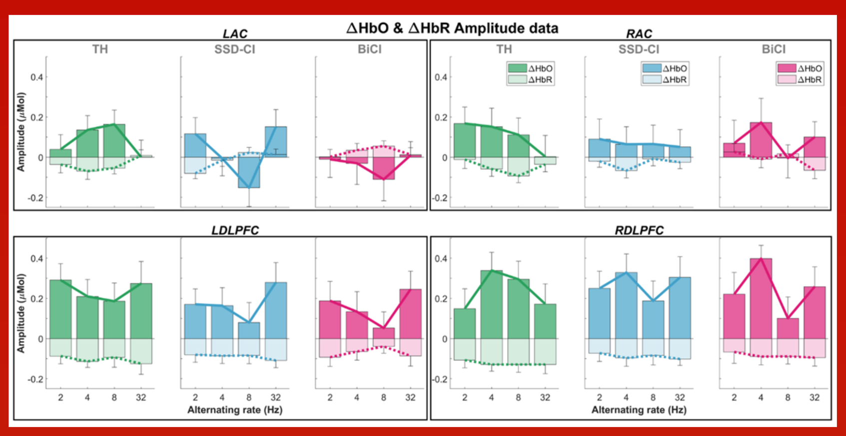

Figure 4: Group-averaged DHbO and DHbR amplitude data, in the cortical regions of interest (ROIs). Amplitudes are plotted across alternating rates, and error bars correspond to ± 1 standard error of the mean (SEM). Connecting lines between amplitude bars (solid = DHbO, dotted = DHbR) demonstrate overall patterns in amplitude changes across alternating rates. Columns contain data from one speech condition, and black boxes contain data from one cortical ROI.

OUTCOMES:

Figure 3 shows that speech intelligibility scores were at ceiling levels across all rates for the nondegraded condition. For the bilateral CI condition, there is reduced performance with a minimum at 4 Hz. The SSD-CI condition does not show a similar “V” shape, but comparisons of typical-hearing and SSD-CI scores between 2 – 32 and 4 – 32 Hz suggest that switching attention between normal and degraded speech at low alternating rates reduces speech understanding.

Figure 4 demonstrates cortical activity (fNIRS response) in the four cortical regions of interest, expressed in terms of changes in relative concentration of oxygenated and deoxygenated hemoglobin (ΔHbO and ΔHbR, respectively). The AC and DLPFC exhibited significantly different activity across alternating rates in the non-degraded condition, with altered activity patterns in both regions in the SSD-CI and bilateral CI conditions.

FURTHER FUNDING HAS ENABLED US TO EXPAND OUR RESEARCH TO:

Evaluate the relationship between binaural hearing (spatial release from masking) and listening effort in listeners with SSD-CI, using pupillometry as an objective measure of attention and effortful cognitive processing.

Suveg L, Thakkar T, Burg E, Godar SP, Lee D, Litovsky RY. The Relationship Between Spatial Release From Masking and Listening Effort Among Cochlear Implant Users With Single-Sided Deafness. Ear Hear. Published online February 19, 2025. doi:10.1097/AUD.0000000000001611

LAY SUMMARY OF FINDINGS AND IMPLICATIONS OF THIS RESEARCH:

In the present study, we demonstrate that cortical activity in the four regions of interest suggests employment of different listening strategies across the four alternating rates. Addition of degraded speech in one or two ears alters patterns of auditory cortex and dorsolateral prefrontal cortex activity across alternating rates compared to the non-degraded speech condition. These findings suggest that degraded speech inputs in one or two ears impacts cortical integration of binaural speech stimuli in ways not necessarily revealed by behavioral data alone. In the future, objective neuroimaging data in clinical settings may better inform auditory rehabilitation techniques to improve cochlear implant outcomes.