11th International Brain-Computer Interface Meeting 2025 DOI: 10.3217/978-3-99161-050-2-236

Improving Speech Perception Through Brain-Driven Target Speech Selection

Vishal Choudhari[1,2], Maximilian Nentwich[3], Sarah Johnson[3], Stephan Bickel[3], Ashesh D. Mehta[3], Adeen Flinker[4], Daniel Friedman[4], Edward F. Chang[5], Nima Mesgarani[1,2*] (nima@ee.columbia.edu)

[1]Columbia University, [2]Mortimer B. Zuckerman Mind Brain Behavior Institute, [3]Northwell Health, [4]New York University School of Medicine, [5]University of California San Francisco

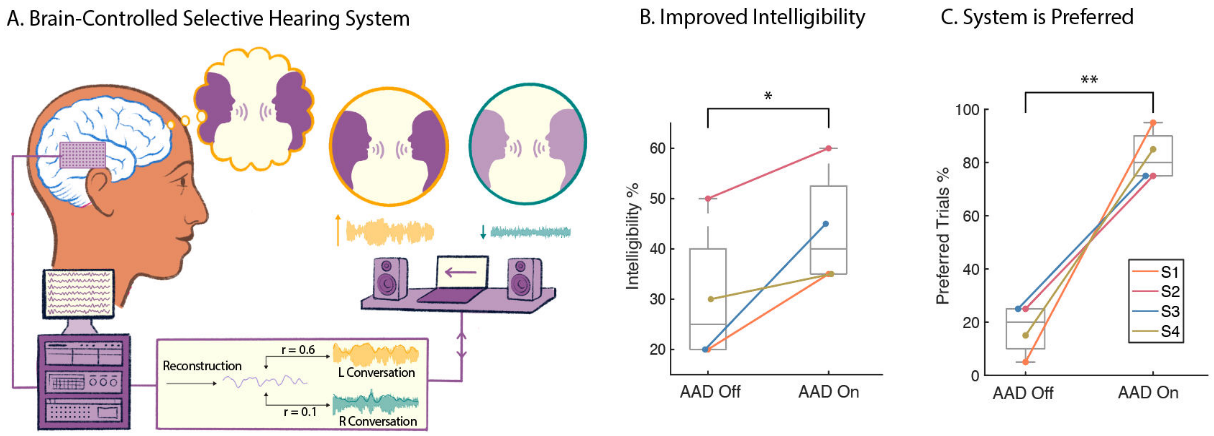
Introduction: Environments with multiple competing conversations and background noise create significant challenges for focusing on a single speaker, particularly for individuals with hearing difficulties. Current hearing aids rely on techniques like directional microphones and beamforming, which often fail to align with the wearer's dynamic listening intent. Auditory attention decoding (AAD) presents a promising alternative by using neural data to identify the listener's target of attention and selectively enhance the desired speech signal relative to background noise.

Gap: While extensive research has focused on improving AAD algorithmic accuracy in offline settings, there has been limited exploration of real-time, closed-loop systems. Existing non-invasive approaches, though valuable, often exhibit slower response times and reduced accuracy. Importantly, no prior studies have demonstrated improved listening outcomes such as speech intelligibility or listening effort reduction. This leaves a critical gap in understanding the practical benefits of real-time AAD systems.

Methods: We developed and evaluated a real-time closed-loop AAD system (Figure 1A) with four self-reported normal-hearing participants (S1-S4) implanted with brain electrodes during epilepsy treatment. Participants were tasked with focusing on one of two competing conversations while the system dynamically adapted to their attention shifts.

Results: Utilizing invasive electroencephalography (iEEG), the system accurately decoded and enhanced the attended conversation. This led to significant improvements in speech intelligibility (Figure 1B) and reduced listening effort (Figure 1C), as corroborated by pupillometry. Importantly, participants could seamlessly switch attention between the two competing conversations, with the system adapting dynamically to their shifts in focus. All participants reported that the system would be useful, and psychophysical testing on individuals with hearing impairments further validated its effectiveness.

Significance: This study is the first to demonstrate that real-time, closed-loop AAD can improve both objective and subjective hearing outcomes. By bridging the gap between decoding success and practical auditory benefits, this work marks a significant step toward the development of brain-controlled hearing devices capable of improving auditory experiences in challenging listening environments for both normal-hearing and hard-of-hearing individuals.



Published by Verlag der Technischen Universität Graz