A Listening Effort Based Comparative Analysis of CROS Hearing Aids and Bone-Anchored Hearing Devices for Single-Sided Deafness Patients

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1 Introduction

Single-sided deafness (SSD), the near or total loss of hearing in one ear with normal hearing in the contralateral ear, presents significant challenges, including speech-in-noise recognition difficulties, impaired sound localization, and reduced awareness of sounds in the affected auditory hemifield. Current therapeutic approaches aim to improve processing of sounds from the impaired hemifield by rerouting signals to the contralateral non-impaired ear. This can be achieved, for instance, through air conduction using contralateral-routing-of-signal (CROS) hearing aids, or bone conduction using bone-anchored (BA) hearing devices.

While SSD patients report perceived benefits from BA and CROS devices, documenting these benefits using clinical measures has proven challenging. Consequently, the optimal choice between these devices remains uncertain, creating an ongoing dilemma in the clinical management of SSD. The lack of objective assessment regarding the reported reduction in listening effort and differences in funding modalities for each device contribute to a long-standing controversy.

This research project aims to address this long-standing controversy by investigating which device yields superior hearing outcomes for SSD patients. Behavioral (NASA Task Load Index) and pupillometric measurements were used to evaluate the cognitive effort required when SSD patients perform speech-in-noise recognition tasks. The full results presented this year expand upon the preliminary findings reported at the AWC 2023 conference and have the potential to provide the first comprehensive evidence to guide the management of SSD, maximizing patients' benefit, and offering evidence-based justification of funding policies.

2 Material and method

2.1 Participants

Thirteen adult patients (7 men, 6 women) with single-sided sensorineural deafness participated in this study. Single-sided sensorineural deafness was defined as the absence of residual bone conduction hearing and no residual speech recognition in one ear, while the other ear exhibited air conduction audiometric thresholds equal to or better than 25 dB HL between 250 Hz and 4 kHz. All participants were native English speakers without a history of neurological disorders, excessive caffeine intake prior to the measurement session, or any otologic co-morbidity in the unaffected ear. Throughout the study, participants remained seated in a comfortable chair within a double-walled audiometric booth situated in the MUHC Department of Speech Pathology and Audiology. The research protocol was reviewed and approved by the Research Ethics Board (REB) of the MUHC. Prior to their participation in the study, informed consent was obtained from all participants.

2.2 Experimental Procedure

Behavioral performance was evaluated using the Hearing-In-Noise Test (HINT) [1] conducted using the Oticon Medical Experiment Platform (OMEXP) under three different conditions: while wearing a CROS hearing aid (Oticon CROS with OpenSoundNavigator™ 2), while wearing a BA hearing aid (Oticon Medical Ponto™ 4), and without any hearing aid. Twenty sentences were presented in each condition (BA-fitted, CROS-fitted, and unaided), for a total of 60 sentences. Speech signals were presented using a frontal loudspeaker, while white noise was presented using a second loudspeaker placed on the same side as the better ear. The stimulation levels were determined by performing an adaptive HINT prior to the experiment to identify the signal-to-noise ratio (SNR) that corresponded to a 70% speech reception threshold (SRT) without a hearing aid. Participants were instructed to listen to the sentences and repeat them aloud, with no feedback provided.

During the execution of the behavioral task, the Pupil Core eye-tracking platform (Pupil Labs, Berlin, Germany) was used to measure pupil size and location in both eyes. The peak pupil dilation (PPD) was calculated during the time interval between the offset of the sentence and the prompt to repeat it [2], and subsequently averaged across sentences within each condition.

Upon completion of each condition, a subjective assessment of listening effort was conducted using the NASA Task Load Index (NASA-TLX) via a tablet computer. This subjective and multidimensional assessment tool was used to evaluate participants' mental workload level (MWL) during the task of repeating sentences heard in noise.

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3 Results

Results reveal no significant effect of the device on behavioral performance (HINT scores, Fig. 1A), consistent with previous reports [3, 4]. Peak pupil dilation results indicate that both CROS and BA hearing aid conditions require less cognitive effort compared to the unaided (UNAI) condition (Fig. 1B). Subjective effort ratings suggest a diminished perception of cognitive effort among participants when utilizing BA hearing aids during a speech-in-noise task (see Fig. 1C). The higher frustration induced by the requirement of bilateral in-ear devices in CROS hearing aids could explain the differences between the UNAI and BAHA conditions (see Fig. 1C), when considering the subjective assessment of cognitive effort that incorporates evaluations of frustration and physical demand.

4 Conclusion and Future Work

The paradigm presented in this study investigates the integration of objective and subjective methodologies as a valuable tool for selecting appropriate devices in patients with single-sided deafness (SSD). Results confirm a reduced cognitive effort in aided SSD patients, despite no observed behavioral improvement. Each dimension of the MWL assessments will be analyzed to evaluate their impact on participants' perception of cognitive effort. This study constitutes the first step towards a research project aiming to develop an objective biomarker for personalized recommendations and longitudinal tracking of patients' progress in clinical settings.

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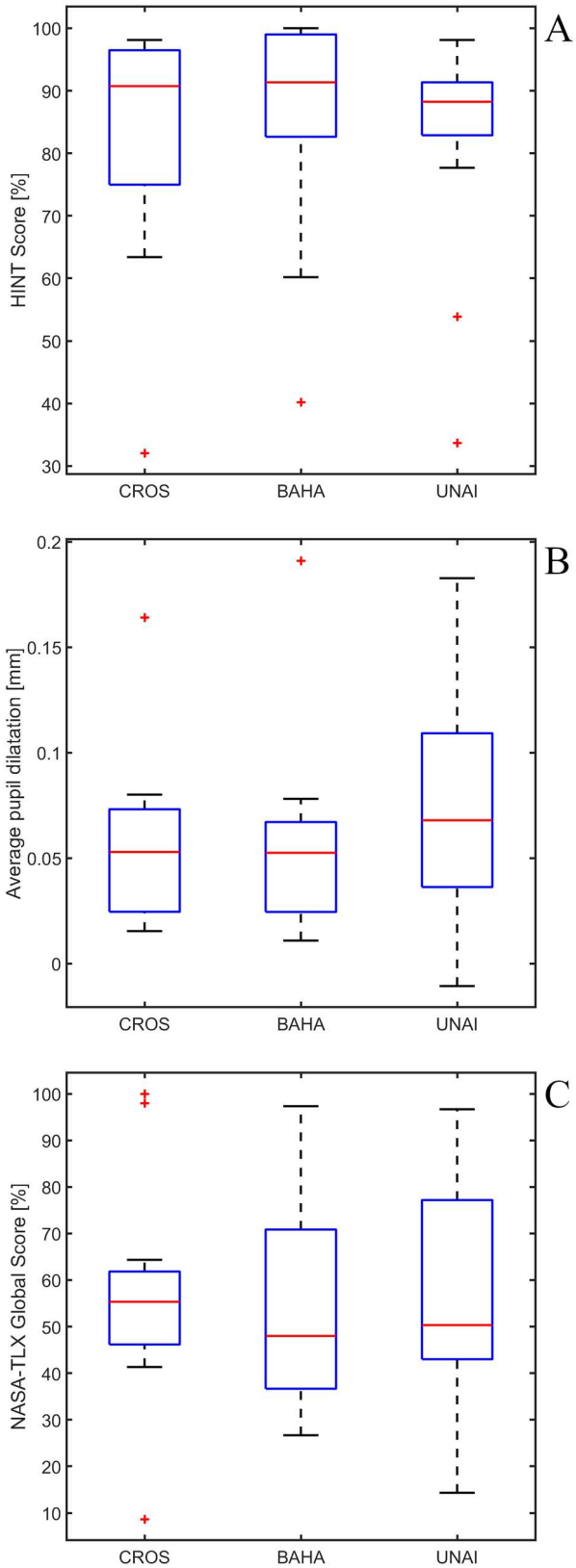

Figure 1: Behavioral (A), objective (B), and subjective (C) results obtained with thirteen SSD patients, with hearing aids (BAHA and CROSS conditions) and without hearing aid (UNAI condition). Medians are indicated by red central marks and outliers are plotted using "+" red markers