Speech Recognition in Noise with Four Remote Microphone Technologies

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Introduction

A remote microphone is a wireless transmitter that routes audio signals to a hearing aid. Remote microphones provide a direct audio input that results in a consistent input level to the hearing aid, overcoming the negative effects of talker distance, ambient noise, and reverberation (Chisolm et al., 2007). Traditionally, remote microphone technology was most often used in educational settings in the form of frequency modulated, or FM, systems.

This study documented speech recognition in noise with four commercially available remote microphone systems. Each of the four systems used a different wireless audio transmission protocol:

- Frequency Modulation (FM)
- Wireless Bluetooth® paired with near-field magnetic induction (NFMI)
- 2.4 GHz
- 900 MHz

Methods

Participants

Sixteen adults aged 52 to 81 years (mean = 68.5 years) with mild to moderately-severe, sensorineural hearing loss participated in this study. Ten out of sixteen participants were regular hearing aid wearers and none had remote microphone experience. All participants were financially reimbursed for their participation in the study and completed an informed consent process that reviewed study methodology, their required involvement, and any risks or benefits.

Devices

Commercially available behind-the-ear (BTE) hearing aids, remote microphone systems, and programming software from three hearing aid companies were used in this study. Each bilateral set of hearing aids was paired with the respective, compatible remote microphone system(s). All participants were fit with occluded, full shell custom earmolds; each earmold used a standard size 13 tube.

Verification

Real-ear measures were completed using an Audioscan Verifit. All hearing aids were prescribed to age appropriate DSL v5.0 targets (Scollie et al., 2005). Remote microphone transparency was confirmed for all fittings, ensuring that the hearing aid output matched prescribed targets in all test conditions. Verification of the remote microphone in-situ output was done at test condition distances to allow for contribution of the direct acoustic pathway to the measurement. When the test condition combined the hearing aid micro-phones with the remote microphone, the audio mixture was set to equal levels for both in-puts.

Test Material

The Hearing in Noise Test (HINT) was used in its adaptive form during which the noise was presented at a fixed level (55 dB SPL) and the sentence levels were varied depending on the accuracy of the listener's response. The HINT SNR-50, or the signal-to-noise ratio required for correct repetition of 50% of the sentences, was recorded for the hearing aid only, remote microphone only and hearing aid microphone plus remote microphone conditions. Each condition was assessed one time using two lists (20 sentences for each condition). The speech was presented at 0° azimuth while continuous, speech shaped noise was presented from four speakers surrounding the participant (45°, 135°, 225°, and 315°). Participants were tested at 6 and 12 feet from the talker loudspeaker. The order of remote microphone conditions was counterbalanced across participants.

Methods

Test Conditions (26 Total)

1.) Unaided (6 Feet and 12 Feet)

2.) Omnidirectional Hearing Aid Microphone Only (6 Feet and 12 Feet; 3 different sets of hearing aids)

3.) Remote Microphone Streaming Only (6 Feet and 12 Feet; 4 remote microphone systems)

4.) Remote Microphone Streaming + Hearing Aid Microphone (6 Feet and 12 Feet; 4 remote microphone systems; remote microphone/hearing aid mix)

Testing was done over two visits. Three microphone conditions for two remote microphone systems were evaluated at each visit: hearing aid only, remote microphone only and remote microphone plus hearing aid microphone. The HINT sessions were at least two weeks apart to mitigate any learning effects.

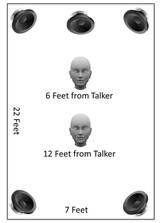

Figure 1. Five speaker array used for HINT testing. In the test set-up, the average Reverberation Time (RT-60) was 0.4 seconds across frequency and the Direct to Reverberant Ratio was 6dB.

Results

Box plot whiskers represent the 5th and 95th percentiles and the shaded box shows the 25th and 75th percentiles. Mean is shown as the dotted line and the median performance is the solid black line inside the box. Asterisks indicate significant improvement in HINT SNR-50 when compared to unaided and any hearing aid only condition (p <0.001).

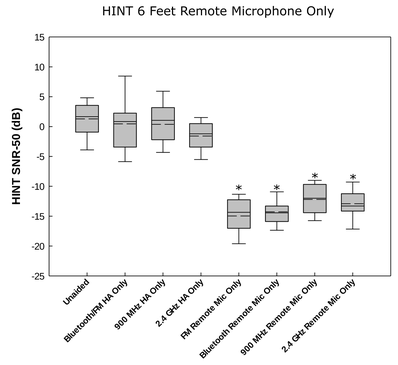

Figure 2. HINT SNR-50 is shown as a function of microphone condition. In the figure above, participants were seated **6** feet from the talker. The remote microphones were streaming only (no contribution from the hearing aid or environmental microphone).

Results

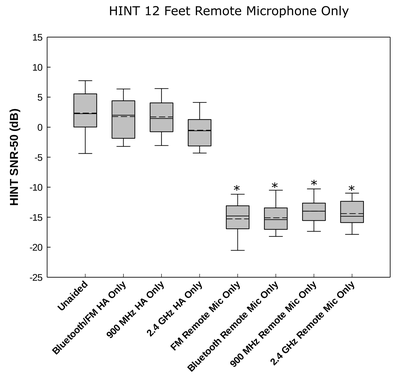

Figure 3. HINT SNR-50 is shown as a function of microphone condition. In the figure above, participants were seated **12** feet from the talker. The remote microphones were streaming only (no contribution from the hearing aid or environmental microphone).

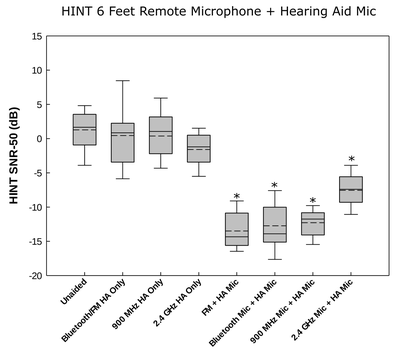

Figure 4. HINT SNR-50 is shown as a function of microphone condition. Participants were seated **6** feet from the talker. The remote microphones were set such that there was equal contribution from the hearing aid microphone and the remote microphone.

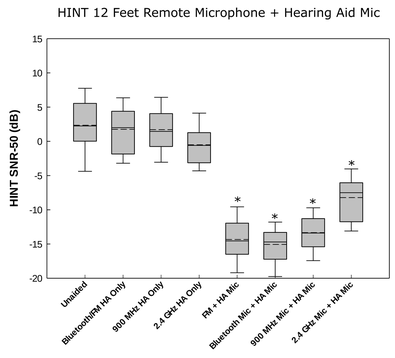

Figure 5. HINT SNR-50 is shown as a function of microphone condition. Participants were seated **12** feet from the talker. The remote microphones were set such that there was equal audio contribution from the hearing aid microphone and the remote microphone.

Results

Four RMANOVAs were completed for the conditions shown in Figures 2-5; each showed a significant main effect of microphone condition: $F(7,105) = 233.5$, p <0.001 for six feet remote microphone only; $F(7, 105) = 255.2$, p <0.001 for 12 feet remote microphone only; $F(7,105) = 149.4$, p <0.001 for 6 feet remote microphone plus hearing aid microphone and $F(7,105) = 214.8$, p <0.001 for 12 feet remote microphone plus hearing aid microphone. Post-hoc analyses used Tukey's pairwise multiple comparison test, meaningful observations are discussed below.

- Performance with remote microphone streaming significantly increased speech recognition in noise when compared to the hearing aid only condition across all four remote microphone systems when participants were seated both 6 feet and 12 feet from the talker (p <0.001).
- Performance with the combination of remote microphones and hearing aid microphones significantly increased speech recognition in noise when compared to the hearing aid only condition across all four remote microphone systems when participants were seated both 6 feet and 12 feet from the talker (p <0.001).
- No difference was observed between remote microphone only performance when participants were seated both 6 feet and 12 feet from the talker (p >0.05).
- Performance was similar between three of the four remote microphone conditions when the hearing aid microphone was introduced.

Discussion

The results of this study agree with previous reports of remote microphone benefit. Participants in this study demonstrated significantly improved speech recognition in noise when comparing remote microphone streaming, both with and without the hearing aid microphone enabled, to hearing aid only and unaided listening. This benefit was observed with all four of the tested remote microphone systems.

As expected, distance between the participant and talker did not affect the benefit that the participants received. However, it was unexpected that performance was similar when comparing remote microphone test conditions with and without the hearing aid microphone activated. Previous reports of this comparison suggest that remote microphone benefit would decrease with activation of the hearing aid microphone (Boothroyd & Iglehart, 1998). We speculate that the noise levels used in this study were not sufficiently high to cause the expected effect. Future studies using a test protocol that allows for higher noise presentations levels may reveal this effect.

Though not discussed in detail here, the observed benefits were acoustically predictable in nature. Of clinical note, proximity of the remote microphone to a talker's mouth greatly affects the quality and level of the transmitted signal. Successful use of any remote microphone technology should include counseling on proper use and orientation.

References

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