Effect of Assistive Listening Systems on Intelligibility Metrics in Various Real-World Environments

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Presented at the Annual meeting of the American Academy of Audiology, Seattle, WA, April 2023

Starkey

Hear better. Live better.

INTRODUCTION

It is widely accepted that wireless assistive listening systems effectively improve the signal-to-noise ratio (SNR) and perceptual speech intelligibility for hearing aid and cochlear implant users. In laboratory environments, the efficacy of directional microphones has been measured to range between 1-6 dB in SNR improvement, depending on the amount of venting in the user's ear coupling and the degree of hearing loss[1,2]; whereas wireless remote microphones and FM systems have been demonstrated to provide even greater degrees of improvement (6-16.8 dB) depending on listener distance and the amount of signal contribution from an environmental microphone in the wearer's hearing device[3].

There are many other uncontrolled factors that could impact the degree of potential benefit of assistive listening systems when they are used in ecological listening environments. This poster presents objective speech intelligibility analyses to help characterize the degree of real-world benefits of using public assistive listening systems to wirelessly deliver audio signals to hearing aids via the induction coils (i.e., telecoils) that are commonly embedded in hearing instruments.

METHODS

To assess the real-world benefit of public hearing assistive technology, we developed a research firmware variant for commercially-available hearing aids that allowed the devices to wirelessly stream their audio input signals to a smartphone application for storage. Since current practice guidelines advise that fitting telecoils for use with induction hearing loops "remains the most widespread and effective way to hear well in public spaces,"[4] we configured the devices to stream either their induction coil or microphone audio input signal. Using this system with a binaural set of hearing aids, it was possible to obtain synchronous recordings from both a hearing aid microphone and induction coil, unobtrusively, while the hearing aid wearer listened in various ecological environments where assistive hearing accessibility systems were available.

After the hearing aid wearers returned from the field, the stored recordings could then be analyzed offline. Due to the ecological nature by which field audio samples were collected, a clean-speech reference signal was not available to support an intrusive analysis like the short-time objective intelligibility (STOI) measure, and the non-intrusive version of the STOI (NI-STOI) is less accurate[5]. However, Betlehem and colleagues[6] presented an efficient and effective non-obtrusive methodology which employed the Google Speech-to-Text (STT) recognizer for objectively comparing speech-intelligibility performance differences between various audio-signal processing treatments when applied to real-world speech samples.

Additionally, an analysis of both the original and our systematically re-recorded QuickSIN speech corpus, with known 5 dB SNR steps, was conducted to help contextualize the STT recognizer's output. For the laboratory reference analysis, recordings were made while a talking manakin played the QuickSIN speech corpus with surrounding multi-talker babble from other speakers. A podium microphone, placed within 4 inches of a talking manakin's mouthpiece, was used as the input to a hearing loop system calibrated to the IEC 60118-4 standard. The Google STT analysis was then compared to scores obtained from hearing-impaired subjects (n=20).

RESULTS

LABORATORY REFERENCE ANALYSIS USING ORIGINAL & RE-RECORDED QUICKSIN

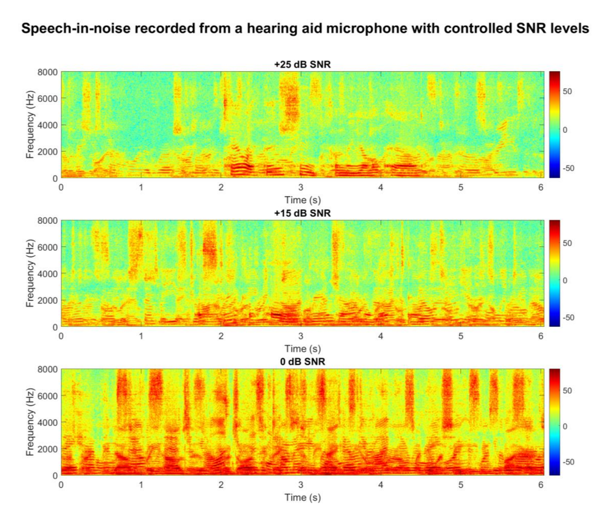

Fig 1. Spectrogram of hearing aid microphone recordings made in a sound field with known +25, +15, and 0dB SNR levels.

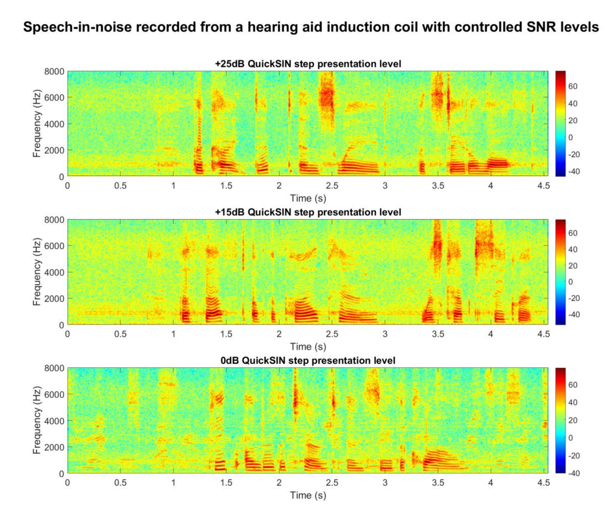

Fig 2. Spectrograms of hearing aid induction coil recordings made using a hearing loop with a podium microphone input close to the source.

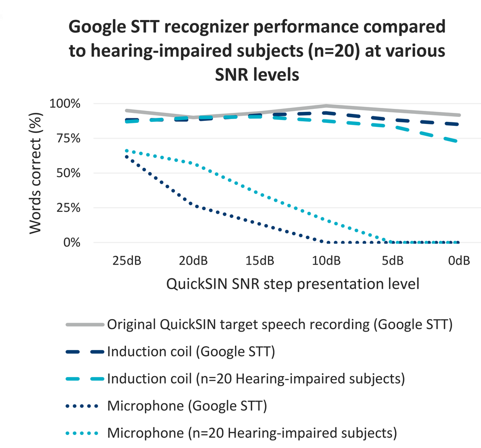

Fig 3. Performance of the Google STT recognizer when analyzing original and re-recordings of the QuickSIN in comparison to hearing-impaired listeners (n=20) tested in the same laboratory setup.

The Google STT recognizer correctly identified 91.8% of the words in the relatively clean recording of the speech-only channel of the original QuickSIN. Hearing-impaired subjects (n=20) and the Google STT showed similar performances when detecting words from the telecoil recordings, which were obtained during sound-field presentation of the QuickSIN test in noise. When using the hearing aid microphone instead, subjects' performance was somewhat better than the Google STT, but both followed a downward trend as the SNR became less favorable. These data provide a basis for understanding how Google STT recognizer performance relates to SNR.

EFFECT OF MICROPHONE SELECTION ON PUBLIC ADDRESS SYSTEM BENEFIT

Comparison of recordings from two different city hall meetings demonstrated disparities in Google STT recognizer performance that are likely due to the type of microphone system that was used as an input to the public address and hearing loop systems. The use of podium microphones yielded markedly higher performance than the use of a boundary microphone array. In our samples, the use of a boundary-microphone array as the input to the hearing loop was counter-productive to the purpose of hearing accessibility systems.

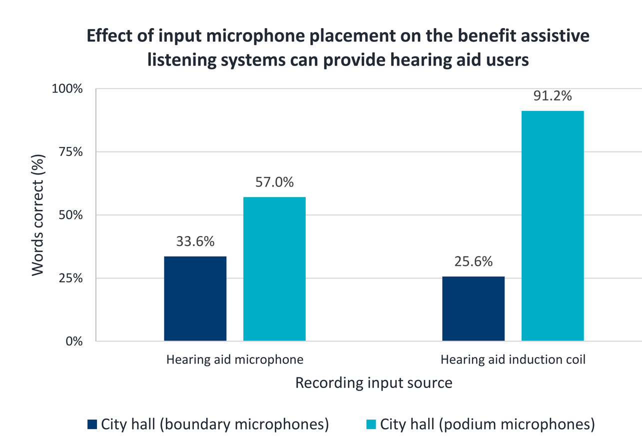

Fig 4. Comparison of Google STT recognizer accuracy for two types of sound system inputs. A human scorer recognized 866 words in the podium microphone recordings and 780 words in the boundary microphone array recordings.

ASSISTIVE LISTENING SYSTEMS REDUCE EFFECTS OF REVERBERATION & NOISE

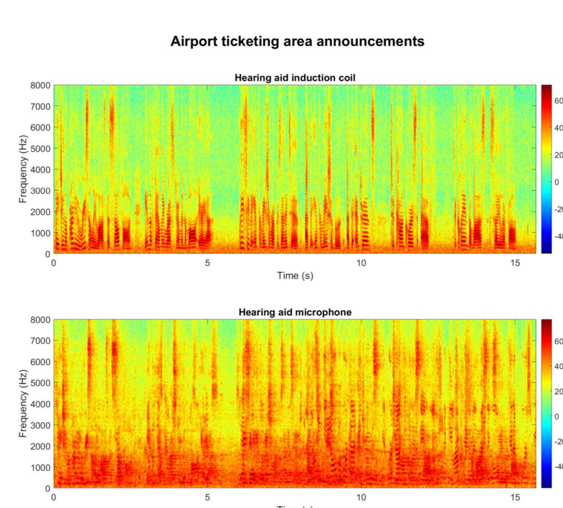

Fig 5. Spectrograms of synchronous hearing aid microphone and induction coil recordings of a public address announcement in the departures area of the Minneapolis-St. Paul Int'l Airport.

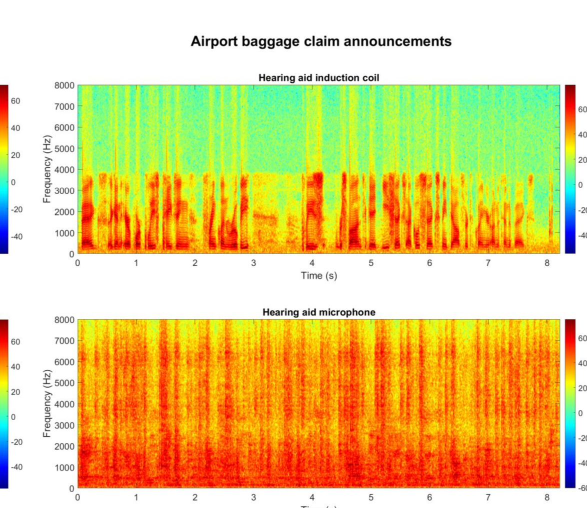

Fig 6. Spectrograms of synchronous hearing aid microphone and induction coil recordings of a public address announcement at baggage collection area of the Minneapolis-St. Paul Int'l Airport.

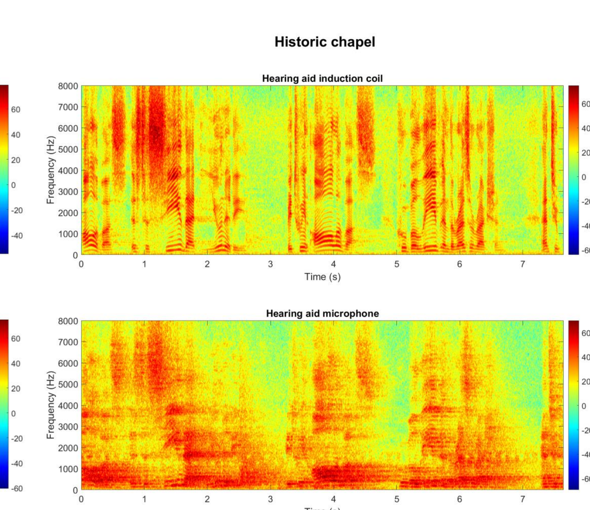

Fig 7. Spectrograms of synchronous hearing aid microphone and induction coil recordings in a small, but reverberant, place of worship.

RESULTS (CONT.)

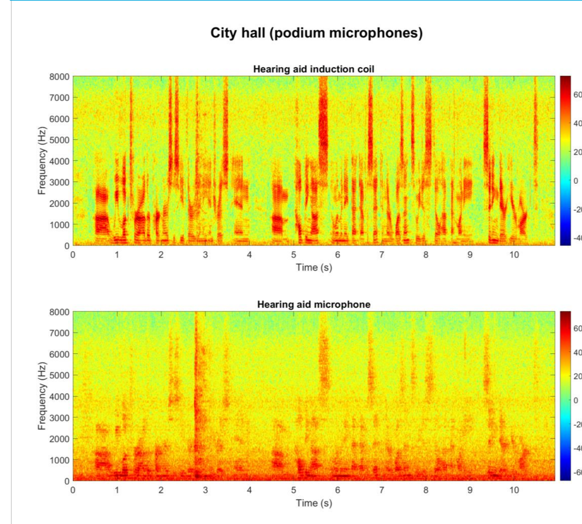

Fig 8. Spectrograms of synchronous hearing aid microphone and induction coil recordings of a city hall meeting where podium microphones were used.

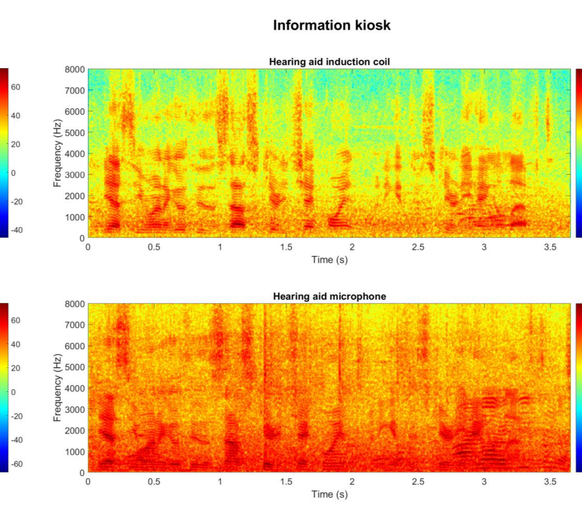

Fig 9. Spectrograms of synchronous hearing aid microphone and induction coil recordings at a help desk with a boundary microphone hearing loop input.

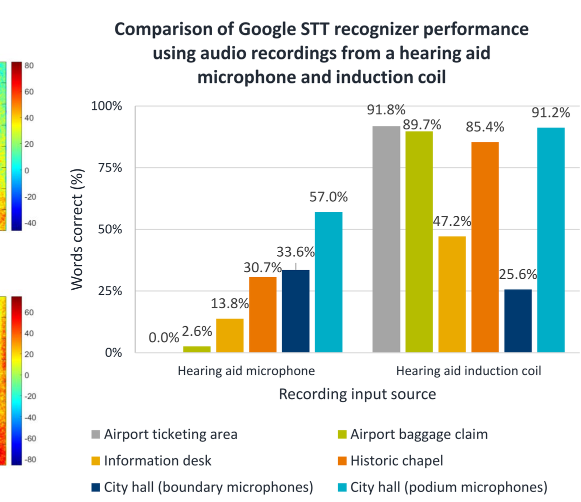

Fig 10. Google STT recognizer performance for hearing aid microphone and induction coil recordings in various real-world situations.

Audio demonstrations available	Total words detected			Words correct		Average STT Confidence	
	Human (Ground truth)	Hearing Aid Microphone	Hearing Aid Induction coil	Hearing Aid Microphone	Hearing Aid Induction coil	Hearing Aid Microphone	Hearing Aid Induction coil
City hall (boundary microphones)	780	328	220	262	200	0.873	0.869
City hall (podium microphones)	866	585	837	494	790	0.876	0.942
Historic chapel	652	301	588	200	557	0.811	0.929
Airport baggage claim	78	9	75	2	70	0.580	0.940
Airport ticketing area	61	2	59	0	56	0.977	0.925
Information desk	528	99	287	73	249	0.805	0.874

Table 1. The total number of words detected by a human scorer and the Google STT recognizer. The Google STT recognizer output was compared to the ground-truth, normal-hearing-human observations to determine the number of words correctly detected using the hearing aid microphone and induction coil recordings. The Google STT recognizer provides a confidence value for each word detected, which has previously been used to objectively compare intelligibility differences[6].

DISCUSSION

- Public hearing assistive technology was shown to provide an SNR improvement in a variety of real-world listening situations that were equivalent to ~5-30dB.
- Boundary microphones were less effective than podium and lapel microphones.
- Facility operators should install public hearing assistive technology (e.g., hearing loops) to reduce the effects of noise, distance, and reverberation in order to help facilitate equitable communication access.
- Hearing healthcare providers should consider public hearing assistive technology compatibility with induction coils when making hearing aid recommendations.

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