Multi-Mic+ closes the hearing in noise gap

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Abstract

The Multi-Mic+ is the first digital wireless remote microphone for hearing aids based on Bluetooth® Low Energy (LE) Audio and is Auracast™ capable. Remote microphones used with hearing aids can effectively mitigate or eliminate the damaging effects of background noise, distance to desired sound, and reverberation on speech understanding. This increases the utility of hearing aids. The study described in this paper included 4 groups of 15 participants each with varying hearing loss severities, and validated that the Multi-Mic+ provides high benefit in a challenging listening environment compared to state-of-the-art hearing aid directionality alone. This benefit was shown to be available to users across hearing loss severities. In addition, results indicated that a mix-in streaming approach maintains benefit while allowing access to surrounding sounds, so users are not cut off from what is happening around them.

Remote microphones are assistive listening devices that can help hearing aid users get more benefit out of their hearing aids. The basic function of a remote microphone is to collect the sound of interest very near the source and transmit it to the hearing aids. This is a well-established way to circumvent the issues of noise, reverberation and distance in different listening environments and situations. These three factors diminish the benefit of hearing aids in understanding speech.

The potential of remote microphones to provide Signal-to-Noise Ratio (SNR) improvement is extensive and vastly greater than hearing aids alone.[1,2,3] Although the benefit of onboard directionality in hearing aids has improved markedly,[4,5,6] it is based on spatial separation of the desired sound and the surrounding noise, works best at distances of 1 to 2 meters from the desired sound, and is still susceptible to degradation in reverberant environments. Therefore, remote microphones remain a powerful tool for any hearing aid user needing more help hearing in specific situations and environments.

Many studies of remote microphones have been done as laboratory experiments without actual use of the devices in real life situations. In a 2004 study, Boothroyd[3] demonstrated benefit of a remote microphone combined with hearing aids both in the lab and in the field. Yet, despite perceived benefit in real life usage, surprisingly none of the people in the study stated an intent to purchase such a system. What has and has not changed in the 20 years since the Boothroyd study?

One thing that has not changed is the potential benefit. Wireless technology in remote microphones has advanced from analog FM to digital radio frequency transmission, with most current solutions operating in the 2.4 GHz band. While this technology advancement has advantages that include less susceptibility to interference, privacy of transmissions, and compatibility with other digital wireless inputs (e.g. the same digital wireless antenna in the hearing aid can also be used to receive streamed audio from a TV streaming accessory or a smartphone), the SNR benefit relative to older technology is very similar. The SNR improvement when using a remote microphone placed near the desired sound source has been shown to be independent of the specific wireless technology that is used.[7]

What has changed over the years is that remote microphones for use with hearing aids have become more attractive, usable and affordable, and are now widely compatible with different styles of hearing aids. Each of these modern advantages are exemplified in the Beltone Multi-Mic+. Twenty years ago, using a remote microphone required wearing Behind-The-Ear (BTE) hearing aids with a direct audio input connection so that a receiver module could be attached. It could be a bit clunky and not in line with users' wishes for hearing aid style. On top of that, these solutions tended to come at a significant added cost.

The Multi-Mic+, shown in Figure 1, is not only tiny, but also compatible with all Beltone Serene™ hearing aids at all technology levels that have wireless capability, as well as Beltone hearing aids with wireless capability in the future. It is rechargeable with a whole day's use on one charge

and streams high quality audio using the Bluetooth Low Energy protocol. Furthermore, the Beltone Multi-Mic+ is also an Auracast device. This means that it is ready to broadcast audio to an unlimited number of hearing aids as well as any other devices that can receive Auracast transmissions.

In addition to picking up acoustic sound via either directional or omnidirectional microphones for streaming to the hearing aids, the Multi-Mic+ accepts telecoil, FM, and line-in signals, and streams them to the hearing aids. This means that the hearing aids themselves don't need to have dedicated hardware connections for different types of input signals, so the hearing aid user has access to them with no effect on wearing comfort or appearance of the hearing aids. The Multi-Mic+ also allows for creative ways to transmit audio signals from devices with line out signals directly to users' hearing aids, and finally, the Multi-Mic+ is a modest additional investment to owning hearing aids and maximizing their benefit unlike the costlier FM-based remote microphone systems of the past.

Figure 1

When the Multi-Mic+ user activates streaming, the signal from the Multi-Mic+ is mixed in with the sound in the listening program the user is currently listening to. Most often this will be the default Program 1. App users can adjust the balance between the Multi-Mic+ input and the acoustic microphone input, and even mute the acoustic microphones if desired.

Previous studies with remote microphones have shown greatest benefit with the microphones on the hearing aids muted, so that noise in the environment is not picked up and amplified by the hearing aids. One study of both adults and children showed the average benefit difference to be as large as 4 dB depending on the test conditions and user age.[2] Those authors pointed out that even with reduced benefit, active hearing aid microphones serve the important purpose of allowing users to maintain awareness of their surroundings when using a remote microphone, and that active hearing aid microphones would also enable incidental learning in children who use remote microphones.

We conducted a study with adult hearing aid users to document that the Multi-Mic+ provides equivalent SNR benefit to that reported previously. We also included sufficient participants, including people with normal hearing, to examine whether the SNR benefit provided by the Multi-Mic+ might differ depending on hearing loss severity. Finally, given the mix-in streaming approach where hearing aid microphones are activated by default, we also wanted to investigate how much SNR benefit was preserved relative to the hearing microphones being muted.

Methods

Participants

A total of 60 test adults (46 males and 14 females) participated in this test. The participants were split with 15 participants in each of the following hearing loss categories: participants with normal hearing (Pure Tone Average (PTA) between -10 to 25 dB HL), participants with mild hearing loss (PTA between 26 to 40 dB HL), participants with moderate hearing loss (PTA between 41 to 55 dB HL), and participants with moderately severe to severe hearing loss (PTA between 56 to 90 dB HL). The median age of the participants was 76 years with a first quartile of 58 years and a third quartile of 80 years. The median participant age and quartiles of each hearing loss category increases with level of hearing loss in this test as it does for the general population with hearing loss.[8,9,10,11] The test participants with hearing loss were all experienced hearing aid users with a median of 10 years of experience with amplification (1st quartile: 0 years and 3rd quartile: 20 years). Hearing aid use increases with hearing loss severity as it does for the general population with hearing loss.[12,13]

Hearing aids and fitting

The participants were fitted with Beltone Serene Receiver-In-the-Ear (RIE) hearing aids with the appropriate power receiver (LP, MP, or HP) and Power domes to optimize the signal processing benefit. The hearing aids were fit with the default gain prescription based on the test participants' actual experience level. The hearing aids were fitted with one program, the Hear in Noise program featuring advanced 4-microphone binaural beamforming.[4,14]

Test conditions

- Hearing aids with the Hear in Noise program alone.
- Hearing aids with the Hear in Noise program and hearing aid microphones active combined with the Multi-Mic+.
- Hearing aids with the Hear in Noise program and hearing aid microphones deactivated combined with the Multi-Mic+.

Test material and setup

Testing was completed with the participants seated in a sound booth (setup illustrated in Figure 2). Speech Reception Thresholds (SRTs) were measured for each condition using Dantale II.[15] Speech was presented from 0 degrees, directly in front of the test participants. Speech-shaped noise was presented simultaneously from 75, 90, 180, and 270 degrees. The noise level was constant at 65 dB SPL, while the speech level was varied to find the SNR at which 50% of the words were correctly understood. The hearing aids have adaptive features that rely on identification of speech and noise in the environment. To ensure that all adaptive features were activated during testing, the Dantale II test noise was started 60 seconds before testing was initiated.

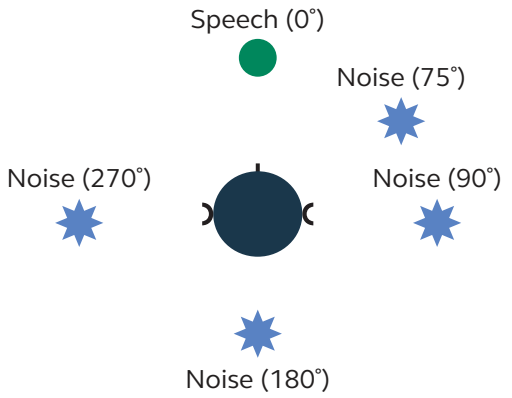

Figure 2. Layout of loudspeaker with respect to test participant when measuring SNRs for a front talker in the three test conditions for hearing speech in noise.

Statistical analysis

The resulting speech reception thresholds for 50% correct performance (dB SNR) was compared across test conditions. The data was analyzed using unpaired and paired t-tests.

Results and discussion

The test participants' mean SRTs for 50% correct performance (dB SNR) when listening to speech while surrounded by noise is shown in Figure 3. Performance is shown for the three test conditions: Hearing aids alone, hearing aids with microphones activated combined with the Multi-Mic+ ("MM+" in figures 3 and 4), and hearing aids with hearing aid microphones deactivated combined with the Multi-Mic+. The results are for all participants combined (e.g. participants with normal hearing and the three groups with hearing loss). The mean SRT for 50% correct performance in noise was -8.5 dB SNR when the participants were listening to speech with the hearing aids alone, -14.8 dB SNR when speech was streamed to the hearing aids via the Multi-Mic+ with the hearing aid microphones activated, and -16.3 dB SNR when speech was streamed to the hearing aids via the Multi-Mic+ with the hearing aid microphones deactivated.

The breakdown of mean improvement, or benefit, in SRT (dB SNR) with the Multi-Mic+ relative to the hearing aids with 4-microphone beamforming for the 4 groups of fifteen participants is presented in Table 1 and the absolute performance per condition and group is shown in Figure 4. Benefit with the addition of the Multi-Mic+ was significant for all groups with the hearing aid microphones active and muted. No differences in benefit were observed among the participant groups, indicating that all can be expected to receive significant benefit using the Multi-Mic+ regardless of hearing loss status. Even those with normal hearing showed remarkable benefit. Remote microphones are sometimes used in treating auditory processing disorders or hidden hearing loss in people who show typical hearing threshold levels, and the current data also supports that the intended effect of helping them to focus in particular situations can be anticipated.

	Multi-Mic+, hearing aid microphones active	Multi-Mic+, hearing aid microphones muted
No hearing loss	6.4 dB SNR (p<0.001)	8.8 dB SNR (p<0.001)
Mild hearing loss	5.8 dB SNR (p = 0.00004)	7.3 dB SNR (p<0.001)
Moderate hearing loss	5.6 dB SNR (p = 0.00007)	6.7 dB SNR (p = 0.00001)
Severe hearing loss	7.6 dB SNR (p = 0.00002)	8.3 dB SNR (p<0.001)
All participants	6.3 dB SNR (p<0.001)	7.7 dB SNR (p<0.001)

Table 1. Mean benefit in SNR improvement with the Multi-Mic+ compared to the hearing aids with 4-microphone beamforming alone for each participant group and all participants combined. A p-value lower than .05 indicates a significant result.

In the current study, we did not test different distances from the desired sound source, as it is proven that the SNR benefit of remote microphones does not diminish with distance as long as the distance does not exceed the wireless connection range.[1,2,7] It is also proven that the performance of hearing aid microphones regardless of whether they are directional or omnidirectional, will be best up to distances of around 1.5m and then taper off dramatically.

We compared the Multi-Mic+ performance to the condition where hearing aid microphones in the Beltone Serene perform best: with the 4-microphone beamformer at an optimum distance from the target sound source. This was to show that, even under the best conditions with the most advanced technology, the Multi-Mic+ gives additional benefit. This anticipated finding was indeed proven across all participant groups in the study and strongly supports the use of the Multi-Mic+ for best speech understanding in difficult listening environments.

As described, the signal from the Multi-Mic+ is by default mixed in the with current listening program that the user hears. With the hearing aid microphones active, the participants could hear the competing noise in the test environment in one test condition. The mean benefit across groups was found to be only 1.4 dB less than when the hearing aid microphones were deliberately muted for the speech-in-noise testing. In other words, participants had almost equal access to an improved SNR for the streamed Multi-Mic+ signal in the default, hearing aid microphones active condition without isolating them from their surroundings. This is important for usability in daily life. Many users will want to be able to keep tabs on what is happening in the environment around them even if they want to put their main focus on one speaker.

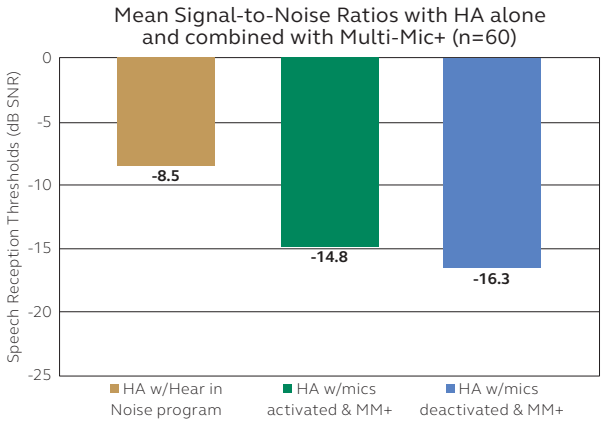

Figure 3: Test participants' mean speech reception thresholds for 50% correct performance (dB SNR) when listening to speech while being surrounded by noise with hearing aids alone, hearing aids with microphones activated combined with the Multi-Mic+, and hearing aids with hearing aid microphones deactivated combined with the Multi-Mic+. Lower dB SNR scores indicate better performance.

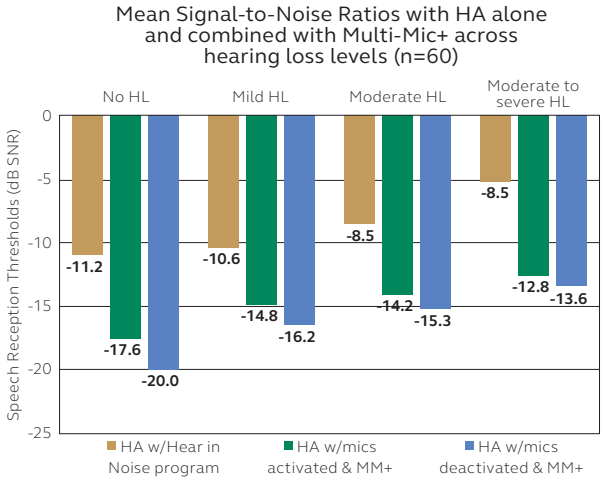

Figure 4: Test participants' mean speech reception thresholds for 50% correct performance (dB SNR) across different levels of hearing loss when listening to speech while being surrounded by noise with hearing aids alone, hearing aids with mics activated combined with the Multi-Mic+, and hearing aids with hearing aid mics deactivated combined with the Multi-Mic+. Lower dB SNR scores indicate better performance.

Conclusions

The Multi-Mic+ provides a streamed SNR benefit to all groups of participants including those with normal hearing, as well as those with mild hearing loss, moderate hearing loss, and moderately severe to severe hearing loss. No significant differences in benefit among the groups was observed.

Test participants on average experienced a 7.7 dB advantage with the Multi-Mic+ over hearing aids alone. This advantage was reduced by an average of only 1.4 dB when the hearing aid microphones were active during streaming from the Multi-Mic+. These results support that the default mix-in streaming approach strikes an excellent compromise between the benefit of Multi-Mic+ streaming and the ability to monitor the surroundings.

The results strongly support the use of the Multi-Mic+ to improve speech intelligibility in noise and assist hearing aid users in getting the most in out of their hearing aids regardless of their listening environments.

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