Unlocking clarity for people with severe and profound hearing losses with streaming accessories

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Abstract

Beltone Boost Max S represents a significant upgrade in hearing aids designed for those with severe and profound hearing losses. Easy-to-use connectivity options are important for this group, and Beltone Boost Max S includes extensive connectivity to smart devices and streaming accessories. This paper investigates the effectiveness of the Beltone TV-Streamer+ and Beltone Multi-Mic+ streaming accessories in enhancing speech recognition for individuals with severe and profound hearing losses. Participants experienced an average advantage of 9.9 dB with the Multi-Mic+ over the hearing aids alone. Results with the TV-Streamer+ indicated a significant improvement in speech recognition scores over the hearing aids picking up the sound acoustically from a sound bar, with an average increase of 24%. The findings underscore the importance of compatibility with streaming accessories such as the Multi-Mic+ and TV-Streamer+ to significantly enhance auditory clarity in challenging listening environments, thereby improving the overall experience for these individuals.

Hearing in noise and at a distance – or both – is challenging for people with hearing loss but especially so for those with severe and profound hearing losses. While high quality amplification and advanced technologies for hearing in noise are helpful, their strengths are greatest within 1.5 to 2 meters from the hearing aid user, and even then, some listening environments continue to be challenging. It is enormously beneficial to mitigate these effects by bringing the desired sound directly to the person's hearing aids via streaming. Beltone was the first to introduce advanced connectivity options to Super-Power Behind-the-Ear (SP BTE) hearing aids and continues to support people with the greatest need with Beltone Boost Max S. With an entirely new rechargeable design and all new technology platform compared to its predecessor, this hearing aid is preferred for sound quality and provides greater hearing-in-noise benefit.[1] In addition, Beltone Boost Max S brings the SP BTE to the forefront of technology within connectivity solutions.

In a comprehensive outline of best practices for helping people with severe and profound hearing losses, a goal in selecting appropriate hearing aids is to "have convenient and reliable connections to hearing assistive technology."[2] The authors recommend considering connectivity options when selecting the hearing aids, with simplicity in mind. The use and therefore benefit experienced can be impacted by how much trouble it ends up being for the hearing aid user to make use of connectivity. For example, how many extra pieces of equipment, including chargers and cables, will they need to have on hand and remember to take with them when away from home?

Beltone Boost Max S is the first hearing aid of its category to provide a comprehensive ecosystem of connectivity options that provide ease-of-use. Compatibility includes streaming from legacy accessories like the Beltone MyPAL and the Beltone TV Link 2 in addition to new streaming technology based on Bluetooth LE Audio and Auracast broadcasts. Bluetooth LE Audio is overtaking Bluetooth classic as the preferred standard for audio streaming, offering greater efficiency and better sound quality. To improve accessibility for users of all kinds of audio receiving devices, Auracast has also been introduced for sharing and broadcasting audio.[3] The Beltone Multi-Mic+ and the Beltone TV-Streamer+ incorporate Bluetooth LE Audio and Auracast. Both of these streaming accessories have been shown to provide substantial benefit to people with mild, moderate and moderately severe hearing losses.[4,5] People with severe and profound hearing losses likely won't benefit to the same degree,[6] but the support they do get remains vital in increasing everyday communication ability and maximizing the utility of hearing aids. To illustrate the degree of benefit that Beltone Boost Max S users can expect with the streaming accessories, 2 studies were conducted. The first study focused on benefit with the Multi-Mic+ remote microphone and the second study focused on benefit with the TV-Streamer+.

Study 1: Speech Recognition with Multi-Mic+

Methods

Participants

Nine adults (7 males and 2 females) participated in this study. The median age of the participants was 77 years with a 1st quartile of 53 years and a 3rd quartile of 83 years. The participants were all experienced users of amplification with a median of 30 years of hearing aid experience with a 1st quartile of 24 years and a 3rd quartile of 32 years. The participants were all current users of premium High-Power (HP) or SP BTE hearing aids from different hearing aid brands.

Hearing aids and fitting

The test participants were fitted with a pair of rechargeable Beltone Boost Max S SP BTE hearing aids using their own closed earmoulds and connected to a Multi-Mic+ streaming accessory. The Multi-Mic+ streams sound directly to the Beltone Boost Max S. The hearing aids were fitted with two programs. One program was the "Hear in Noise" program with "Clear Focus", a 4-microphone beamformer. The other program was a duplicate of the Hear in Noise program, but set to omnidirectional processing instead of Clear Focus. The hearing aids were fitted with gain that matched the gain in the test participants' own hearing aids. The participants were asked whether the test hearing aids sounded like their own devices, and if they needed further fine-tuning. The participants did not need any additional finetuning.

Test conditions

- Hearing aids with the Hear in Noise program including Clear Focus.
- Hearing aids with the Hear in Noise program with omnidirectional processing.
- 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 muted combined with the Multi-Mic+.

Test material and setup

Testing was completed with the participants seated in a sound booth with the setup illustrated in Figure 1. Speech Reception Thresholds (SRTs) were measured for each test condition using Dantale II.[7] 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 signal-to-noise ratio (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. The testing order of conditions and sentence lists were counterbalanced across participants.

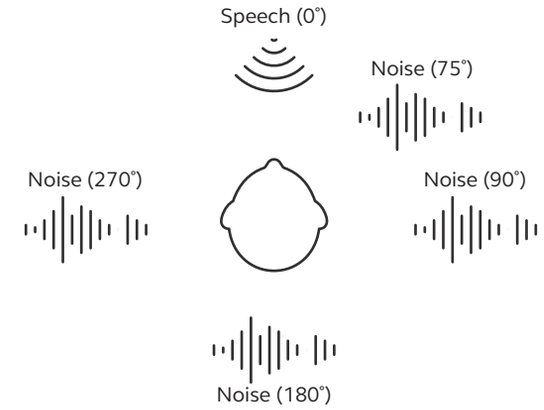


Figure 1. Layout of loudspeaker with respect to test participant when measuring SNRs for a front talker in the four test conditions for hearing speech in noise.

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 2. Performance is shown for the four test conditions.

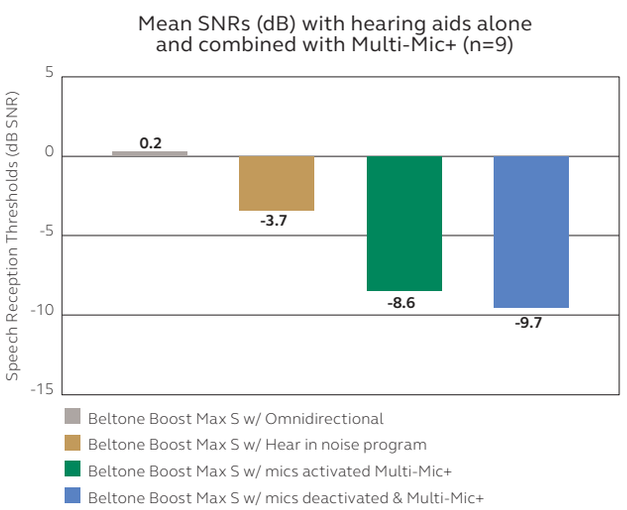


Figure 2. Test participants' mean speech reception thresholds for 50% correct performance (dB SNR) when listening to speech while being surrounded by noise with hearing aids alone (with omnidirectional processing and with Clear Focus), hearing aids with microphones activated combined with the Multi-Mic+, and hearing aids with hearing aid microphones muted combined with the Multi-Mic+. Lower dB SNR scores indicate better performance.

The breakdown of mean dB improvement in SNR, or benefit, with the Multi-Mic+ is presented in Table 1. Benefit with the addition of the Multi-Mic+ was significant both relative to the hearing aids with omnidirectional processing and Clear Focus. The test participants on average experienced a 9.9 dB advantage with the Multi-Mic+ over hearing aids alone with an omnidirectional response. This advantage was reduced by an average of only 1.1 dB when the hearing aid microphones were active during streaming from

the Multi-Mic+. When compared to Clear Focus the average experienced advantage with the Multi-Mic+ was 6.0 dB compared to hearing aids alone. This advantage was likewise only reduced by an average of only 1.1 dB when the hearing aid microphones were active during streaming from the Multi-Mic+. This shows that, even under the best conditions with the most advanced technology, the Multi-Mic+ gives additional benefit and strongly supports the use of the Multi-Mic+ for best speech understanding in noise.

	Multi-Mic+, hearing aid microphones active	Multi-Mic+, hearing aid microphones muted
Omnidirectional processing	8.8 dB ($p < 0.001$)	9.9 dB ($p < 0.001$)
Clear Focus	4.9 dB ($p = 0.002$)	6.0 dB ($p < 0.01$)

Table 1. Mean benefit in SNR improvement with the Multi-Mic+ compared to the hearing aids with omnidirectional processing and Clear Focus alone. A p-value lower than .05 indicates a significant result.

Study 2: Speech Recognition with TV-Streamer+

Methods

Participants, hearing aids and fitting

Seven (6 male and 1 female) of the 9 test participants with severe and profound hearing loss from study 1 participated in this second study on speech recognition with TV-Streamer+.

The test participants were fitted with a pair of Beltone Boost Max S SP BTE hearing aids. The hearing aids were fitted with the default "All-Around" program using Beltone Solus Max. Beltone hearing aids have "mix-in" streaming, meaning that a streamed input to the hearing aids is combined with the microphone input in the program that is active. The gains and features that are active in the program remain active during streaming, but the microphone input can be reduced relative to the streamed input depending on the setting chosen in Beltone Solus Max. The hearing aids were – as in study 1 - fitted with gain that matched the gain in the participants' own hearing aids.

Test conditions, material, and setup

Speech recognition in noise was tested with the Beltone Boost Max S hearing aid microphones picking up sound from a soundbar connected to the TV and with the hearing aids picking up streamed sound from the TV via the TV-Streamer+. In this study, the soundbar was mounted below the TV in accordance with installation recommendations to create the most favorable conditions for listening to the TV aided without streaming. The streaming test condition was tested with hearing aid microphones activated in all noise conditions described below and muted in two of the noise conditions.

The test participants completed a speech recognition in noise test that was a slightly modified version of the Dantale II test.[7] The test is comprised of five-word sentences and was presented in different noise backgrounds that are likely to occur in domestic situations. The noises used were the following four recorded domestic noises: "vacuuming", "cooking", "people talking", and "kids playing". Testing was also performed in quiet for reference. Thirty sentences were administered for each test condition and background combination. Table 2 shows an overview of the test conditions.

Each participant completed a speech recognition test aided with the test hearing aids serving both as practice but also to calculate each participant's reference SNR for the actual test. The practice test was conducted according to the unmodified Dantale II test, where the noise is fixed at 65 dB SPL (no weighting) and the stimulus presentation level is adaptively changed depending on the participant's response, resulting in an SNR for 50% speech recognition. The result of this practice test, minus 6 dB, served as the reference SNR for each test participant. Based on the psychometric function for Dantale II, it was expected that each test participant would obtain a speech recognition score of between 10-40% at their reference SNR if tested in the same background noise. Testing at the individual reference SNR was done for consistency with a previous study[5] where the purpose was to minimize ceiling effects in demonstrating benefit of the TV-Streamer+. The modification of the Dantale II test was to present all sentences at each test participant's individual reference SNR and count the number of correctly recognized words, thereby allowing a % correct score to be calculated for each condition. The maximum speech level used was 75 dB SPL.

Test Condition	Domestic background noises
TV with soundbar	• Vacuuming w/ HA mics unmuted • N/A • Cooking w/ HA mics unmuted • People talking w/ HA mics unmuted • Kids playing w/ HA mics unmuted • N/A • Quiet w/ HA mic unmuted
TV-Streamer+	• Vacuuming w/ HA mics unmuted • Vacuuming w/ HA mics muted • Cooking w/ HA mics unmuted • People talking w/ HA mics unmuted • Kids playing w/ HA mics unmuted • Kids playing w/ HA mics muted • Quiet w/ HA mic unmuted

Table 2. Overview of test conditions.

REAPER Digital Audio Workstation was used to play the background noise from two Genelec 6010 loudspeakers placed 1.2 meters to the left and 1.2 meters to the right of center of the participant's head. The loudspeakers to the left and right of the participant was treated as a stereo pair to play back stereo background noise recordings. The test environment setup is illustrated in Figure 3.

The hearing aids tested have adaptive features that rely on identification of speech and noise in the environment e.g., the environmental classifier which drives automatic changes in hearing aid features such as noise reduction, wind noise reduction, and directionality. Therefore, noise was presented for 1 minute and 15 seconds prior to the first sentence of each speech recognition test to give the hearing aids time to adapt to the environment. The same was true for the test condition without noise: the hearing aids were allowed to adapt for 1 minute and 15 seconds in quiet before the first test sentence was played.

Testing was conducted in a simulated living room with a wall-mounted TV. The audio from the TV was played from a Sonos soundbar connected to the TV. The Dantale II test sentences were played from a laptop through an RME Fireface UFX audio interface. An output of the audio interface was connected to an (line-in) analogue-to-HDMI converter. The output of the converter was connected to an HDMI input of the TV. The target speech was played from either the TV soundbar alone or streamed via the TV-Streamer+. The level of the target speech was calibrated to start at 65 dB SPL when played through the soundbar with competing noise presented according to each participant's individual reference SNR. The level of the TV-Streamer+ was set to default. While streaming, the hearing aids' microphone input was turned down by 3 dB as is the default when streaming from a TV Streamer.

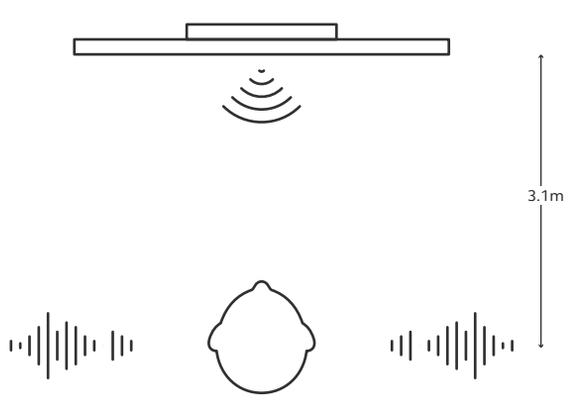


Figure 3. Illustration of the test setup with a wall-mounted TV and loudspeakers playing domestic noises on both sides of the test participant.

Statistical analysis

The resulting speech recognition scores from the test, which were the percentages of words that were repeated correctly, were compared across test conditions. To assess whether there were significant differences between specific conditions, analysis of variance was conducted.

Results and discussion

The test participants' mean speech recognition in noise scores when listening to the TV through the TV soundbar (hearing aids alone) and when listening to the TV with sound being streamed from the TV to the hearing aids via the TV-Streamer+ are shown in Figure 4. The results are for all four domestic noise conditions ("vacuuming"-, "cooking"-, "people talking"-, and "kids playing") combined. The streaming results are for streaming with the hearing aid microphones activated (unmuted). The mean speech recognition in noise score is 31% when listening to speech from the TV soundbar and 55% when speech is streamed to the hearing aids via the TV-Streamer+. Streaming sound from the TV to the users' hearing aids provided a significant mean improvement of 24% points in speech recognition score in domestic noise ($p < 0.001$). When examining individual results, benefit was observed for each test participant. Individual improvements (averaging all noise conditions, and excluding microphones muted conditions) ranged from a score improvement of 9% to 43% points with 6 of the 7 test participants getting a streaming benefit exceeding 10% points in speech recognition in noise.

It is important to note that, with the hearing aid mics active, participants could hear the competing noise. The fact that benefit was still shown demonstrates the value of streaming the TV signal without isolating the hearing aid user from their surroundings. This is important for people who are watching TV together with others or people who want to be able to hear what is happening in the environment around them.

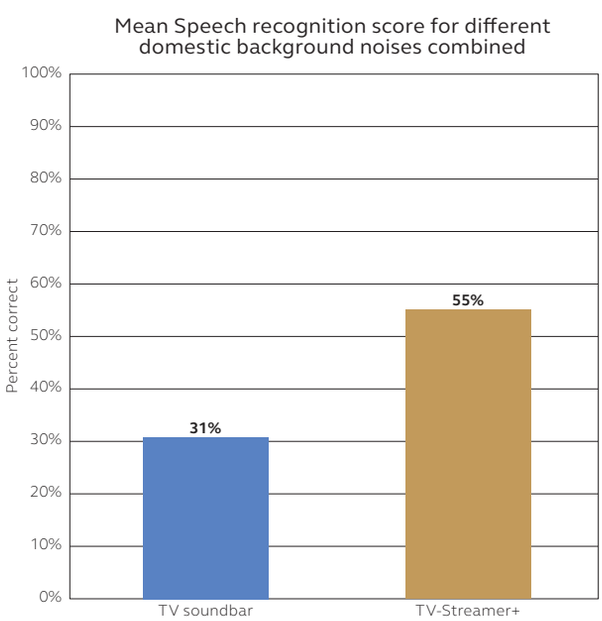


Figure 4: Test participants' mean speech recognition score when listening to speech from the TV with hearing aids alone and with hearing aids combined with the TV-Streamer+ in various domestic background noises combined.

The test participants' mean speech recognition scores in the four different domestic noises: "vacuuming"-, "cooking"-, "people talking"-, and "kids playing" for the two test conditions listening to TV with sound through the TV soundbar and listening to sound streamed from the TV to the hearing aids (with hearing aid microphones activated) are shown separately in Figure 5. The test participants' speech recognition score is improved from 32% to 56% in "vacuuming noise" when the TV sound is streamed to the hearing aids instead of delivered via the TV soundbar ($p = 0.047$). The test participants' speech recognition score is improved 34% points in "cooking noise" ($p = 0.023$), 19% points in "people talking noise" ($p = 0.025$), and 21% points in "kids playing noise" ($p = 0.048$). The streaming benefit is significant in all four domestic background noises with the most benefit obtained in the "cooking" noise.

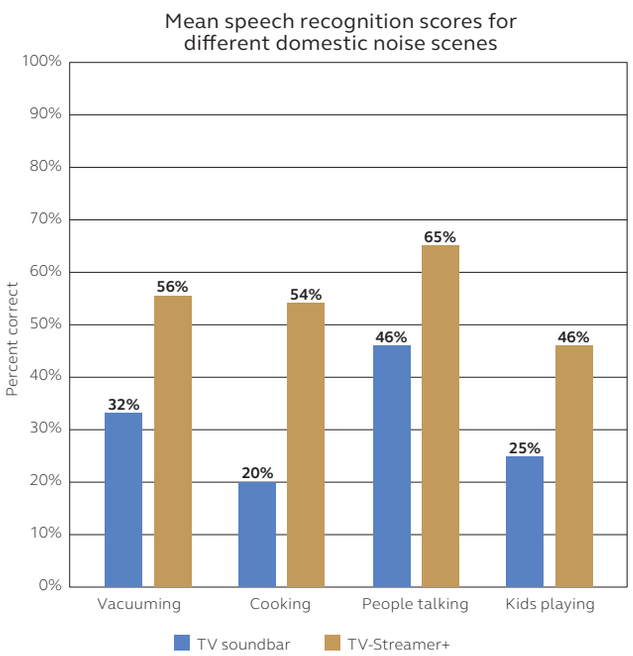


Figure 5: Test participants' mean speech recognition when listening to speech from the TV with hearing aids alone and with hearing aids (hearing aid microphones activated) combined with the TV-Streamer+ in various real-life domestic background noises.

Speech recognition was also tested with the hearing aid microphones muted during streaming in the "vacuuming" and "kids playing" noise conditions. The mean streaming benefit when streaming sound from the TV to the hearing aids via the TV-Streamer+ with and without the hearing aid microphones activated for the two noise conditions is shown in Figure 6. The mean streaming benefit in "vacuuming noise" when streaming sound from the TV to the hearing aids (with hearing aid microphones activated) is 23% points in speech recognition score improvement. Not surprisingly, the mean streaming benefit is even greater when the hearing aid microphones are muted, providing a significant streaming benefit of 56% points. When conducting the analysis of variance, the benefit when muting the hearing aid microphones is found to be significant with respect to the already existing benefit without muting the hearing aid microphones ($p = 0.004$) in "vacuuming noise".

Likewise, the mean streaming benefit in noise increases from 21% points with the hearing aid microphones activated to 66% points with the microphones muted in the "kids playing" noise, providing an added significant benefit of 45% points ($p < 0.001$).

Remarkable benefit of streaming was observed for some test participants who did poorly when listening to the TV soundbar in noise. The greatest individual streaming benefit was a 90% point improvement with streaming and hearing aid microphones muted compared to listening with the TV soundbar in the "kids playing" noise.

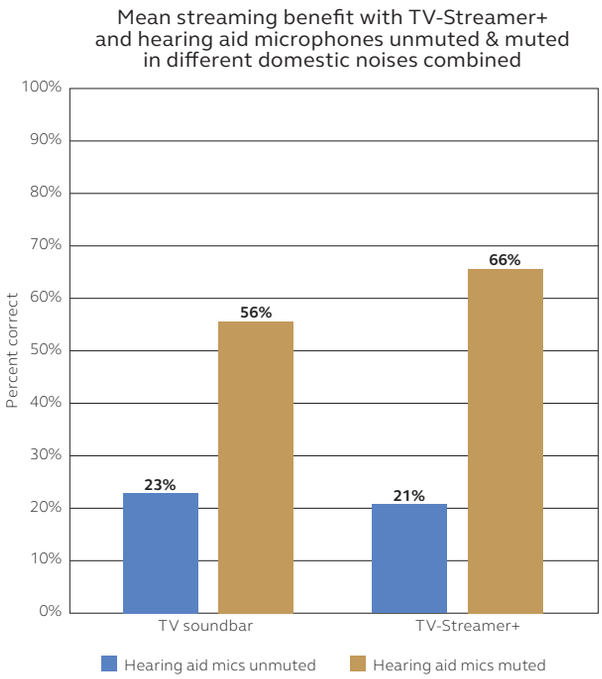


Figure 6: Test participants' mean streaming benefit when listening to streamed speech from the TV via the TV-Streamer+ with and without hearing aids microphones muted.

Speech recognition with the TV soundbar and TV-Streamer+ in various domestic noises was benchmarked against speech recognition in quiet. Figure 7 shows the test participants' mean speech recognition scores in the four domestic noises as well as in quiet for listening to the TV soundbar and to streamed sound via the TV-Streamer+. It is interesting to note that the participants experienced benefit of streaming both with and without the hearing aid microphones muted in all of the noise conditions, but also that they showed a significant benefit of streaming even in quiet. People with less severe hearing loss who participated in an earlier study with the TV-Streamer+[5] performed equally well with and without streaming in quiet. The added benefit for those with severe and profound hearing losses in noise and in quiet underlines how important connectivity can be for them.

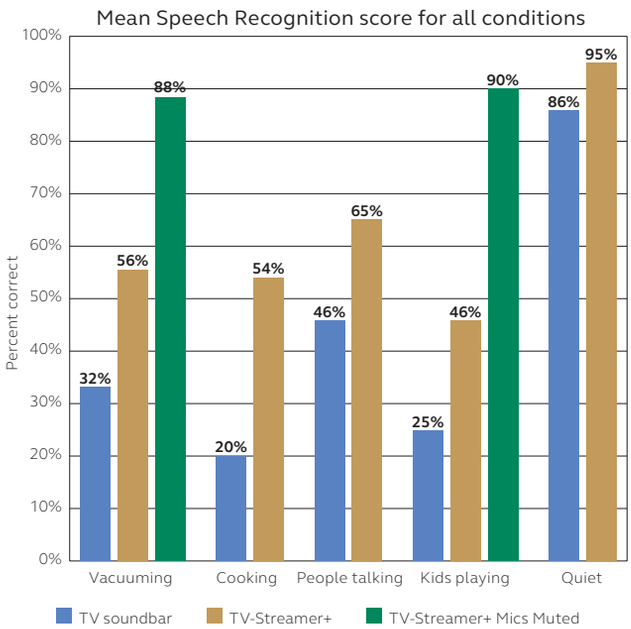


Figure 7: Test participants' mean speech recognition score when listening to speech from the TV with hearing aids alone and with hearing aids combined with the TV-Streamer+ in various domestic background noises and quiet. Error bars show 95% confidence intervals.

Conclusions

As expected, participants in the current study performed less well and showed less benefit across the board than hearing aid users with less severe hearing loss showed in previous studies with the TV-Streamer+ and Multi-Mic+. Participants on average experienced a 9.9 dB advantage with the Multi-Mic+ over hearing aids alone (omnidirectional processing). This advantage was reduced by an average of only 1.1 dB when the hearing aid microphones were active during streaming from the Multi-Mic+.

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

The TV-Streamer+ provides a significant improvement in speech recognition performance in various domestic noises compared to when listening aided to the TV through the TV soundbar alone. Speech recognition performance improves even further when speech is streamed via the TV-Streamer+ to the hearing aids when the hearing aid microphones are muted.

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