

Better TV listening with TV-Streamer+

Charlotte T. Jespersen, Brent Kirkwood, Jennifer Groth

ABSTRACT

People with hearing loss who wear hearing aids are more satisfied with TV listening situations than those who don't use hearing aids, but still report issues. TV accessories that can stream sound from the TV to users' hearing aids can potentially provide further help, but uptake of TV accessories is modest. This study measured speech recognition benefit of the Beltone TV-Streamer+, the first TV streaming accessory based on the Bluetooth® Low Energy (LE) Audio standard. People with hearing loss ranging from moderate to severe were tested in a living room environment with typical domestic noise backgrounds. They performed speech recognition tasks aided with sound presented from a TV via a TV soundbar, the TV-Streamer+ or legacy Beltone Direct TV Link 2. Performance was better with TV-Streamer+ than the TV soundbar in all conditions except "quiet", where performance was comparable when listening aided to the TV soundbar versus streaming. No performance differences were found between TV-Streamer+ and Direct TV Link 2. The results strongly support the use of the TV-Streamer+ to improve TV listening in typical home environments.

Watching TV is a popular leisure activity for many people, and it is no less so for those who wear hearing aids. While hearing aid users' improved communication ability in daily listening environments tends to steal the headlines, improved hearing of the TV is also an important benefit that hearing aid users recognize. In the 2022 MarkeTrak survey, satisfaction "when watching TV with others" was 78% for hearing aid users and only 39% for non-users.¹ This is not to say that hearing aids solve every TV-related complaint. Hearing aid users experience the same difficulties when watching TV as non-users but to a significantly lesser degree, and the top complaints regardless of whether or not people wear hearing aids are related to loudness, understanding speech on the TV program when there were competing sounds in the environment, and effort needed to follow speech on TV programs.² To cope, both hearing aid users and non-users adjust TV volume, which can lead to its own set of issues when others in the surroundings complain about elevated TV volume levels.

Wireless accessories that can connect to TVs and stream sound to hearing aids have been available for many years. Beltone introduced the first of its kind based on digital radio frequency transmission at 2.4 GHz that streamed sound directly from the TV accessory to the hearing aids of the user with no additional body worn device.

To meet the low power consumption requirements of hearing aids, GN engineers designed a proprietary audio streaming protocol based on the power conserving variant of Bluetooth that was intended for transmission of small amounts of data rather than rich content like audio. This solution provided high quality true stereo streamed audio at low latency with power efficiency that was suitable for hearing aids, and was the forerunner for similar proprietary protocols for smart devices.³ Dedicated TV streaming accessories from some other hearing aid brands also followed. But despite the widespread availability and relative low cost of TV streamers as a beneficial accessory to hearing aids, relatively few hearing aid users have them. MarkeTrak¹ found that only 9-10% of people with professionally fitted hearing aids used some kind of streaming accessory and this statistic included the whole category of wireless streaming accessories, not just TV streamers. Use of TV streamers with hearing aids may vary somewhat depending on hearing aid brand although it is likely still quite low. For example, 16% of hearing aid users have used a TV streamer to bring the TV audio to their Beltone hearing aids.⁴

The first TV streamer based on a new standard for wireless audio and hearing aids

The Beltone TV-Streamer+ introduces personal and broadcast streaming based on Bluetooth LE Audio which,

compared to classic Bluetooth, is a better quality and a more power efficient way of transmitting audio from one device – such as a smartphone or streaming accessory – to another – such as earbuds or hearing aids. Like the legacy Direct TV Link 2, users of compatible hearing aids from GN brands can pair their hearing aids to the accessory and receive the streamed sound directly to their hearing aids. In addition, TV-Streamer+ is ready for Auracast™ which will allow owners of TV-Streamer+ to share the broadcast with others who have Auracast compatible devices including headphones, earbuds or even hearing aids from another brand as these become available.

of experience with amplification (1st quartile: 20 years and 3rd quartile: 30 years). The median age of the participants was 79 years with a first quartile of 60 years and a third quartile of 81 years.

The test participants were fitted with a pair of Beltone Serene™ rechargeable micro-Receiver-In-the-Ear (RIE) hearing aids. The hearing aids were fit with the appropriate power receiver (MP or HP), power domes and gain based on the proprietary Audiogram+ fitting rationale for experienced users. The hearing aids were fitted with the default Crosslink Directionality 4 program using

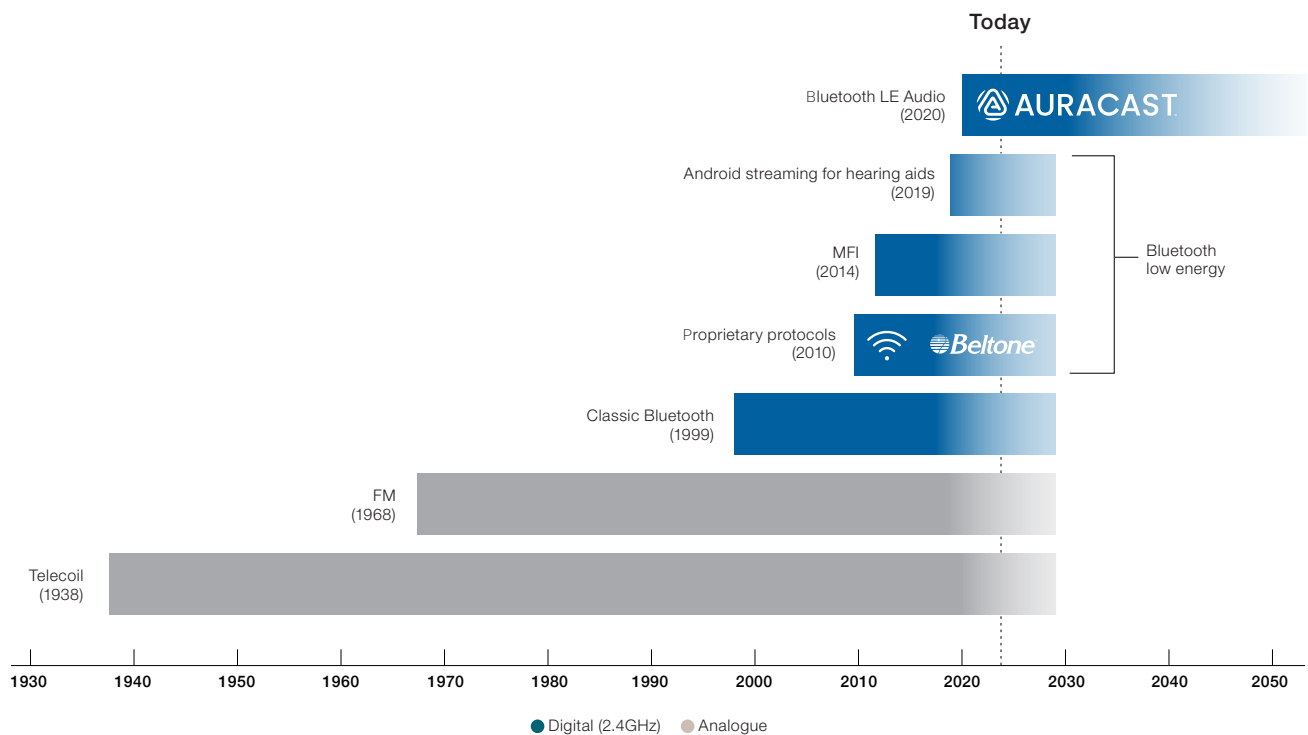


Figure 1. Overview of wireless technology available in hearing aids. Bluetooth LE Audio specifications were released in 2020, and Beltone is the first to introduce hearing aids and wireless accessories incorporating this technology. Although Bluetooth LE Audio has a standardized hearing aid profile, it will also benefit consumers broadly, not just hearing aid users. It is expected to be the preferred audio standard for wireless communication in electronic devices for the next 20 years.

Given the challenges that hearing aid users experience watching TV in their daily environments, it is of interest to explore how much they might benefit from listening via streamed sound versus TV speakers. In addition, the new application of Bluetooth LE Audio in streaming digital wireless audio to hearing aids is relevant to compare to existing solutions. The purpose of the study was to quantify the benefit of listening to sound streamed from the TV-Streamer+ versus from the TV with hearing aid amplification alone in a typical home listening environment. A secondary purpose was to benchmark performance of the TV-Streamer+ against the legacy Direct TV Link 2.

Methods

Participants, hearing aids and fitting

Fifteen individuals with bilateral moderate-to-severe sloping sensorineural hearing loss (12 males and 3 females; 4-frequency average PTA of 63 dB HL right and 64 dB HL left) participated in the experiment. All participants were experienced hearing aid users with a median of 24 years

Beltone Solus Max™ 1.17. 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.

Test conditions, material, and setup

Speech recognition in noise was tested with the hearing aids 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+ and the legacy Direct TV Link 2. A soundbar is a single long speaker containing multiple discrete speakers and is commonly wall-mounted above or below a TV to enhance the audio experience. Many consumers today add soundbars to their TVs to compensate for the poorer sound quality that is a trade-off of the often small, rear-facing built-in speakers for the sleek design of modern flatscreen TVs. 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.⁵ 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 1 shows an overview of the test conditions.

Test condition	Domestic background noises						
TV with soundbar	Vacuuming w HA mics unmuted	N/A	Cooking	People talking	Kids playing w HA mics unmuted	N/A	Quiet
TV-Streamer+	Vacuuming w HA mics unmuted	Vacuuming w HA mics muted	Cooking	People talking	Kids playing w HA mics unmuted	Kids playing w HA mics muted	Quiet
Legacy Direct TV Link 2	Vacuuming w HA mics unmuted	Vacuuming w HA mics muted	Cooking	People talking	Kids playing w HA mics unmuted	Kids playing w HA mics muted	Quiet

Table 1. Overview of test conditions.

Each test participant completed a speech recognition test aided with the test hearing aids serving both as practice but also to calculate each test participant’s reference signal-to-noise ratio (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 and the stimulus presentation level is adaptively changed depending on the person’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 individual. 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 to minimize ceiling effects in demonstrating benefit of the TV-Streamer+. The modification of the Dantale II test was to present all sentences at the individual’s 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.

Adobe Audition 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 test participant’s head. The loudspeakers to the left and right of the test participant were treated as a stereo pair to play back stereo background noise recordings. The test environment setup is illustrated in Figure 2.

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.

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+ or Direct TV Link 2 alone. 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 the individual’s 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.

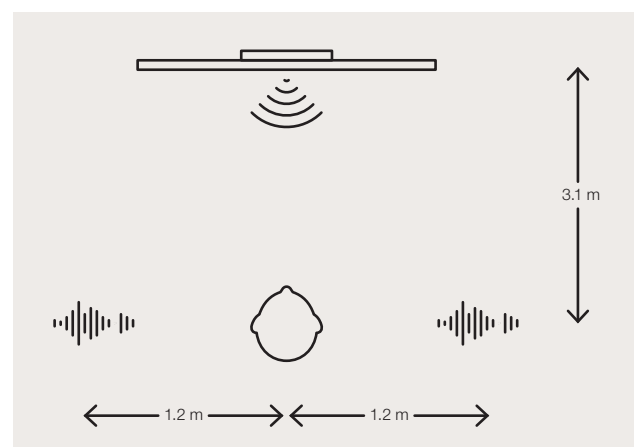


Figure 2. Illustration of the test setup with a wall-mounted TV and loudspeakers playing domestic noises on both sides of the test participant.

Statistical analysis

The resulting speech recognition scores from the test which was the percentages of words understood correctly, were compared across test conditions. The data was analyzed using analyses of variance and using the Tukey’s honest significance test when comparing across multiple conditions.

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 3. 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 55% when listening to speech from the TV soundbar and 85% 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 30% in speech recognition score in domestic noise ($p < 0.001$). When examining individual results, benefit was observed for each test participant. Individual improvements ranged from a score improvement of 8% to 54% with 13 of the 15 test participants getting a streaming benefit exceeding 20% in speech recognition in noise.

It is important to note that, with the hearing aid microphones active, participants could hear the competing noise. The benefit demonstrates a significantly improved SNR for the streamed 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.

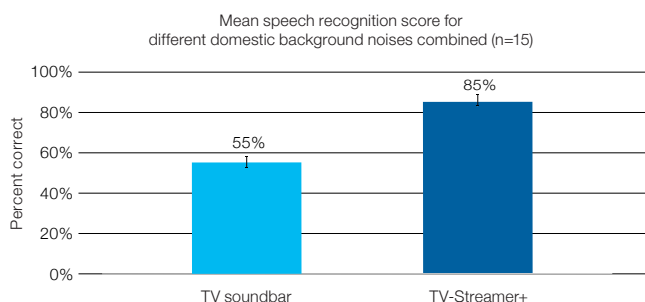


Figure 3: Test participants' mean speech recognition score when listening to speech from the TV with hearing aids alone and with hearing aids combined with the TV-Streamer+ in various domestic background noises combined. Error bars show 95% confidence intervals.

The test participants' mean speech recognition score in the four different domestic noises: "vacuuming", "cooking", "people talking" and "kids playing" noise 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) is shown in Figure 4. The test participants' speech recognition score is improved from 40% to 70% in "vacuuming" noise when the TV sound is streamed to the hearing aids instead of delivered via the TV soundbar ($p < 0.001$). The test participants' speech recognition score is improved 40% points in "cooking" noise ($p < 0.001$), 19% points in "people talking" noise ($p < 0.001$), and 32% points in "kids playing" noise ($p < 0.001$). The streaming benefit is significant in all four domestic background noises with the most benefit obtained in the "cooking" noise.

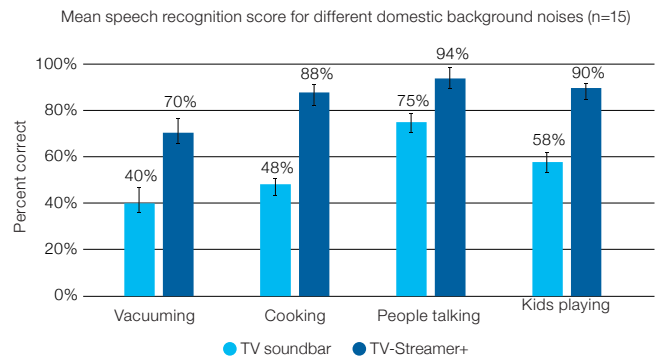


Figure 4: Test participants' mean speech recognition when listening to speech from the TV with hearing aids alone and with hearing aids (hearing aid microphones unmuted) combined with the TV-Streamer+ in typical domestic background noises. Error bars show 95% confidence intervals.

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 5. The mean streaming benefit in "vacuuming" noise when streaming sound from the TV to the hearing aids (with hearing aid microphones activated) is 30% 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 ($p < 0.001$) in "vacuuming" noise.

Likewise, the mean streaming benefit in noise increases from 32% points ($p < 0.001$) with the hearing aid microphones activated to 39% points ($p < 0.001$) with the microphones muted in the "kids playing" noise.

The mean results are limited by some test participants who attained a speech recognition in noise score of 100% when streaming with the hearing aid microphones muted. Despite this test limitation, the mean streaming benefit for the vacuuming noise is an impressive 56% score improvement. On the other side of the coin, 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 70% score improvement with streaming and hearing aid microphones muted compared to listening with the TV soundbar.

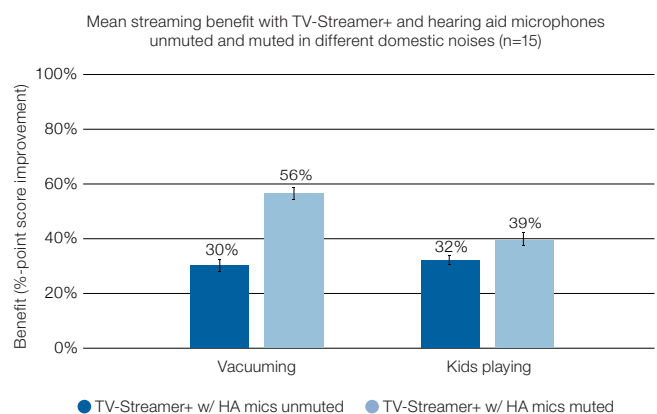


Figure 5: Test participants' mean streaming benefit when listening to streamed speech from the TV via the TV-Streamer+ with and without hearing aid microphones muted. Error bars show 95% confidence intervals.

Speech recognition with the TV soundbar and TV-Streamer+ in various domestic noises was benchmarked against speech recognition in quiet and the legacy Direct TV Link 2. Figure 6 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+ as well as the legacy Direct TV Link 2. Streaming sound from the TV to the hearing aids via the TV-Streamer+ and legacy Direct TV Link 2 provides speech recognition in noise performance that is very close to speech recognition in quiet. There is no significant difference between speech recognition via the TV soundbar in quiet compared to speech recognition in the mean of all the streaming in noise conditions ($p < 0.51$). In contrast, speech recognition in the noise conditions is significantly better with TV-Streamer+ and Direct TV Link 2 than with the sound from the TV soundbar ($p < 0.001$).

Hearing aid users who listen in typical domestic competing noise conditions via either the TV-Streamer+ or the legacy Direct TV Link 2 with the hearing aid mics active can expect to hear the TV as well as when they listen in quiet with the hearing aids only. Listening effort was not assessed in this study and could be higher in the noisy conditions; nevertheless this is still a remarkable benefit.

Mean speech recognition performance with the domestic noises and in quiet are not significantly different for the TV-Streamer+ and legacy Direct TV Link 2 ($p = 0.57$). This shows that the TV-Streamer+ with Bluetooth LE Audio provides similar speech recognition in noise and quiet performance as legacy Direct TV Link 2 with GN's proprietary streaming protocol.

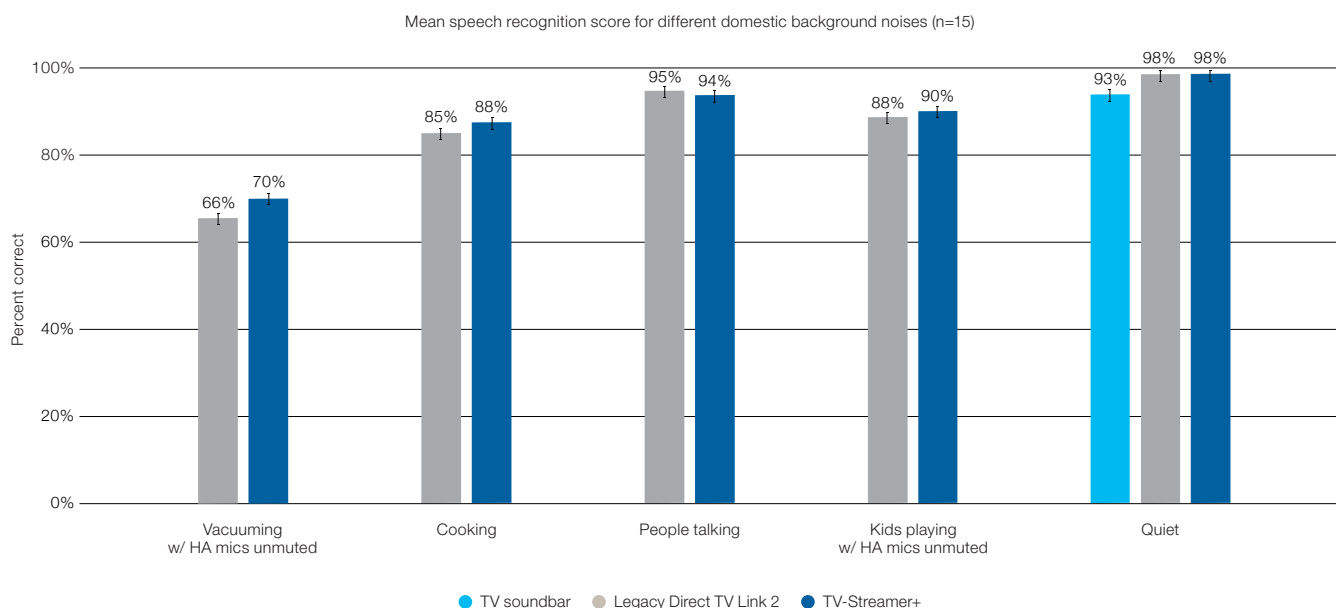


Figure 6: Test participants' mean speech recognition score when listening to speech from the TV with the TV-Streamer+ and legacy TV Link 2 in various domestic background noises and quiet. Error bars show 95% confidence intervals. Results when listening with the hearing aid alone in quiet are included for reference.

Conclusion

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. Streaming speech from the TV in different domestic background noises provides a speech recognition performance that is comparable to speech recognition in quiet when listening aided to sound from the TV soundbar. The speech recognition in noise and quiet benefit provided by the TV-Streamer+ with Bluetooth LE Audio is equivalent to benefit provided by the legacy Direct TV Link 2 with GN's proprietary streaming protocol.

References

1. Picou EM. Hearing aid benefit and satisfaction result from the MarkeTrak 2022 survey: Importance of features and hearing care professionals. In *Seminars in Hearing*. 2022; 43(4):301-316.
2. Strelcyk O, Singh G. TV listening and hearing aids. *PloS one*. 2018 Jun 29;13(6):e0200083.
3. Jespersen CT. A Review of Wireless Hearing Aid Advantages. *Hearing Review*. 2012; 19 (02): 48-55.
4. Groth J, McCoy D. What do owners of hearing aids that stream think of the sound quality? *Canadian Audiologist*. 2023; 10(2). <https://canadianaudiologist.ca/issue/volume-10-issue-2-2023/what-do-owners-of-hearing-aids-that-stream-think-of-the-sound-quality/>
5. Wagener K, Josvassen JL, Ardenkjær R. Design, optimization, and evaluation of a Danish sentence test in noise. *International Journal of Audiology*. 2003; 42:10-17.

Worldwide Headquarters
Belton A/S
Lautrupbjerg 7
DK-2750 Ballerup, Denmark
Tel.: +45 45 75 11 11
belton.com

CVR no. 55082715

