Beltone Boost Max S transforms hearing aids for people with severe and profound hearing losses

Charlotte T. Jespersen, MA; Anne Cathrine Skovlund, MA

Abstract

People with severe and profound hearing losses are a diverse group that typically have more complex listening needs than those with lesser severity of hearing loss. Although they make up a relatively small proportion of hearing aid users, they are often more dependent on their amplification devices in their daily lives and stand to benefit most from advanced technologies. Beltone has demonstrated a deep commitment to serving these individuals by continually offering products that not only have the needed gain and output, but that bring the most advanced technologies. Beltone Boost Max S is a completely redesigned hearing aid that continues to fulfill this promise to those with severe and profound hearing losses. The Beltone Boost Max S is the industry's smallest rechargeable Super Power Behind-the-Ear (SP BTE) device with features that are unusual in this segment, such as state-of-the-art directionality, extensive connectivity options, and full compatibility with Bluetooth LE Audio and Auracast. This paper reports on two studies that quantified different aspects of Beltone Boost Max S including speech recognition in noise compared to legacy technology and other brands' premium SP BTEs as well as listener preference compared to legacy technology. Results support that Beltone Boost Max S represents a major milestone in hearing aids for people with the most severe hearing losses.

With typical hearing aid fittings, providing excellent quality amplification is very often sufficient to improve communication ability both in quiet and noisy environments. In comparison, the relatively smaller and more diverse group of people with severe and profound hearing losses have more complex listening needs that will not be adequately met by typical practice. Although lack of audibility of speech and environmental sound is of obvious concern, other key issues can include significant challenges in social participation, health, and overall quality of life requiring a more comprehensive and often multidisciplinary approach to optimize positive outcomes. Well-fit hearing aids are a cornerstone of treatment and Beltone has demonstrated a commitment in tailoring hearing aids to this specific population. Prior to Beltone Boost, hearing aids for those with severe and profound hearing losses prioritized high gain and output, but little else. Beltone hearing aids for people with severe and profound hearing losses brought not only quality amplification with flexible fitting strategies, but also leading technology within wireless connectivity. The Beltone Boost line of SP BTE hearing aids has been unique in serving this group by continually updating the hearing aids with the most advanced technology.

Beltone Boost Max S is the 5th generation of premium SP BTE designed for people with severe and profound hearing losses. This hearing aid embodies a unique approach to using artificial intelligence in ways that support rather than replace the human's innate ways of listening and navigating in their sound environments. Following this approach, artificial intelligence handles classification of sound environments, automatic hearing all-around and spotlighting speech without feedback. The hearing aid user's brain is provided with the necessary information allowing them to be in control of what they want to listen to. Key aspects of Beltone Boost Max S are summarized below.

1. **Complete redesign**: Beltone Boost Max S is completely new inside and out, from the advanced chip to basic electroacoustics and state-of-the-art features to a premium color palette, improving all aspects of user experience and performance. Of note is the small size and introduction of rechargeability that supports more than all-day wear even with audio streaming.

2. **Advanced sound processing**: Beltone Boost Max S is designed to provide superior amplification for individuals with severe-to-profound hearing loss. As always, it incorporates evidence-based technology that enhances sound quality and user experience. The latest 4-microphone beamforming technologies in both the default listening program as well as the selectable "Hear in Noise" program enable better speech recognition in noise than ever before.

3. **Fitting Flexibility**: Beltone Boost Max S offers a range of fitting options to accommodate the diverse needs of users. This flexibility is crucial as individuals with severe-to-profound hearing loss often have varying preferences for gain and performance. In our research,[1] comparisons of fine-tuning data for people with severe and profound hearing losses compared to those with mild and moderate hearing losses demonstrated equal average fine-tuned gains but an incredible difference in variance. Seventy-five % of the fine-tuned gains for those with mild and moderate hearing losses fell within 2 dB of the median compared to 14 dB for those with the most severe hearing losses.

4. **Connectivity Options**: Like its predecessors, Beltone Boost Max S supports a comprehensive ecosystem of connectivity, allowing users to connect to various audio sources, including smartphones and other digital devices. Onboard telecoil provides direct access to loop systems and compatible phones, which remains important for these individuals. As an industry first, this hearing aid uses Bluetooth LE Audio for the clearest streamed audio. People with severe and profound hearing loss also benefit immensely from remote microphone technology. With compatibility to the Multi-Mic+, Beltone Boost Max S users show a streaming benefit of 9.9 dB.[2]

5. **CrossLink Directionality 4**: The automatic listening program enhances the listening experience by analyzing the acoustic environment and optimizing microphone settings. This feature is particularly beneficial in complex listening situations, allowing users to focus on conversations even in noisy environments. The rationale behind CrossLink Directionality 4 has formed the basis of the Beltone default listening program for more than 15 years (see Jespersen & Groth, 2022[3] for a review).

6. **Feedback Management**: The advanced feedback management system Feedback Eraser 2 prevents unwanted feedback squealing, which is a common issue in high-gain fittings. This feature is among the industry's fastest to eliminate feedback, but without compromising gain.[4]

Because of these many improvements compared to previous Beltone Boost generations of hearing aids, meaningful and measurable user benefits could be anticipated with Beltone Boost Max S compared to legacy technology. One of the most significant challenges for anyone with hearing loss even when wearing hearing aids is hearing in noise. This difficulty is even more pronounced for those with severe and profound hearing loss, as succinctly captured by Souza et al (2018)[5] in their observation that "a listener with severe hearing loss is likely to work harder but understand less." Therefore, it is of great interest to quantify improvements with Beltone Boost Max S in this area. With a special focus on hearing in noise, two studies were carried out to learn how the Beltone Boost Max S might provide additional benefit over legacy technology to users with severe-to-profound hearing loss.

The first study contrasted speech recognition in noise benefit with the Hear in Noise program for new versus legacy technology as well as premium SP BTE hearing aids from other brands. The second study compared sound quality preferences for the new versus legacy technology in both quiet and noisy conditions. This was included because sound quality preferences can reveal global benefit that is not captured by speech recognition in noise testing. For example, it is established that reduction in listening effort can be measured at higher signal-to-noise ratios (SNRs) than are required for maximum speech understanding.[6] It was anticipated that factors such as listening effort, clarity, and pleasantness of sound might contribute to preferences.

Study 1: Speech intelligibility in noise

Methods

Participants

There were 9 test participants (2 female and 7 male) in the speech recognition in noise test. The participants' median age was 77 years with a 1st quartile of 58 years and a 3rd quartile of 83 years. They all had bilateral severe-to-profound sensorineural hearing loss and were experienced hearing aid users with a median of 31 years of experience with amplification (1st quartile of 23 years and a 3rd quartile of 37 years). The participants were all current users of premium High-Power or SP BTE hearing aids from different hearing aid brands.

Hearing aids and test conditions

The test participants were fitted with two pairs of SP BTE hearing aids from Beltone: Beltone Boost Max S and legacy Beltone Boost Ultra using their own closed molds. They were also fitted with 4 pairs of SP BTE hearing aids from other premium hearing aid brands. All hearing aids were fitted with gain that matched the gain in the test participants' own hearing aids. The reason for this is that people with severe-to-profound hearing loss typically have many years of hearing aid experience, and they tend to have strong gain preferences.

Their hearing aids have often been fine-tuned multiple times by their audiologist to preferred optimum settings. This was indeed the case for the 9 test participants in this test; they were all satisfied with the amplification in their own hearing aids. The test 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.

All hearing aids tested were fitted with two programs. One was the dedicated program for each brand that is intended for improved hearing in noise. All of these programs feature directionality. For Beltone Boost Max S, the directional feature is an upgraded 4-microphone beamformer called “Clear Focus”. For Beltone Boost Ultra, the directional feature is a device independent 2-microphone adaptive directional algorithm called “Smart Beam”. For all hearing aids, the second program was a duplicate, but set to omnidirectional to allow calculation of directional benefit for each hearing aid.

Test material and setup

The participants completed a modified version of the Dantale II speech intelligibility in noise test.[7] Dantale II is comprised of 5-word sentences and was presented in a background of static speech-shaped noise at 65 dB SPL. Thirty sentences were administered for each test condition. The level of the speech was manipulated to determine a speech reception threshold (SRT) of 50% correct performance, resulting in a dB SNR score, with better performance revealed through lower dB SNR scores. To ensure that all adaptive hearing aid features were activated during testing, the Dantale II test noise started 60 seconds before testing was initiated. The test was conducted in an idealized situation to maximize possible benefit from the directional features.

Testing was completed with the participants seated in a sound booth with speech presented at 0 degrees azimuth, and static noise presented at 75 degrees azimuth to the right. The positioning of the competing noise in the front plane was intended to highlight the stronger directional response which can also be thought of in terms of a narrower directional beam. The setup is illustrated in Figure 1. The Dantale II speech and noise material was band-pass filtered from 550-4000 Hz to increase task difficulty and avoid ceiling effects in this test setup. The bandpass filtering was performed in Adobe Audition using the FFT filter plugin, with as steep as possible ramp-up and ramp-down of the filter. The testing order of conditions and sentence lists were counterbalanced across participants.

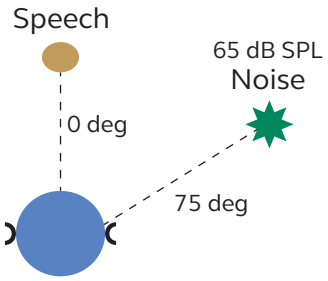


Figure 1. Test setup used for measuring SRTs with adaptive SNRs for a front talker.

Results

The test participants’ mean speech recognition in noise performance was 6.2 dB SNR for 50% SRT with omnidirectional processing and -2.1 dB SNR for 50% SRT with the Beltone Boost Max S upgraded 4-microphone beamformer, Clear Focus. The test participants’ mean speech recognition in noise performance with Beltone Boost Ultra was 4.6 dB SNR with omnidirectional processing and -1 dB SNR with Smart Beam.

Both Beltone Boost Max S and Beltone Boost Ultra provided a significant directional benefit with their strongest directional options compared to omnidirectional processing. The Beltone Boost Max S Clear Focus provided a significant directional benefit of 8.3 dB ($p<.01$) while Smart Beam in Beltone Boost Ultra provided a significant directional benefit of 5.6 dB ($p<.04$). Clear Focus provides an additional benefit of 2.7 dB over Smart Beam.

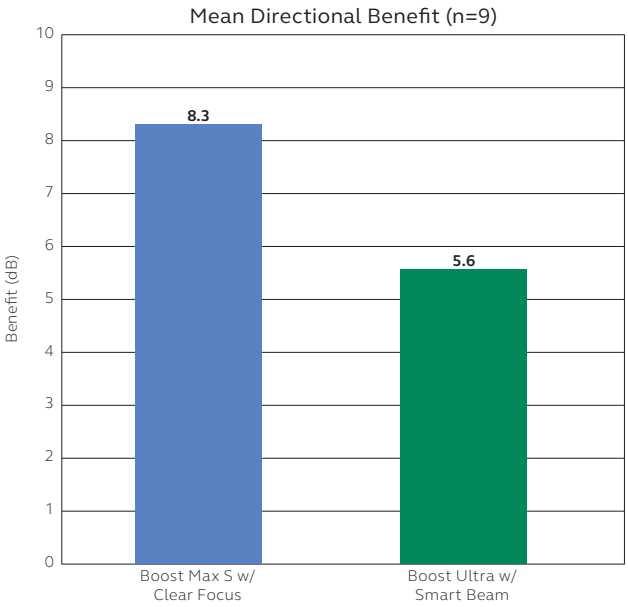


Figure 2. Test participants’ mean directional benefit with Beltone Boost Max S and Beltone Boost Ultra hearing aids.

The mean directional benefit with the Beltone Boost Max S Hear in Noise program and the hearing aids from other premium brands in their hearing aid programs corresponding to the Beltone Hear in Noise program are shown in Figure 3. All hearing aids tested provided a significant directional benefit ($p<.05$).

The directional benefit of 8.3 dB provided by Beltone Boost Max S is significantly better than the directional benefit provided by brands C and D, but not significantly better than the directional benefit provided by Brands A and B. This result is not surprising as Brands A and B also use 4-microphone beamforming similarly to Beltone Boost Max S whereas the other brands use device independent 2-microphone beamforming similarly to Beltone Boost Ultra.

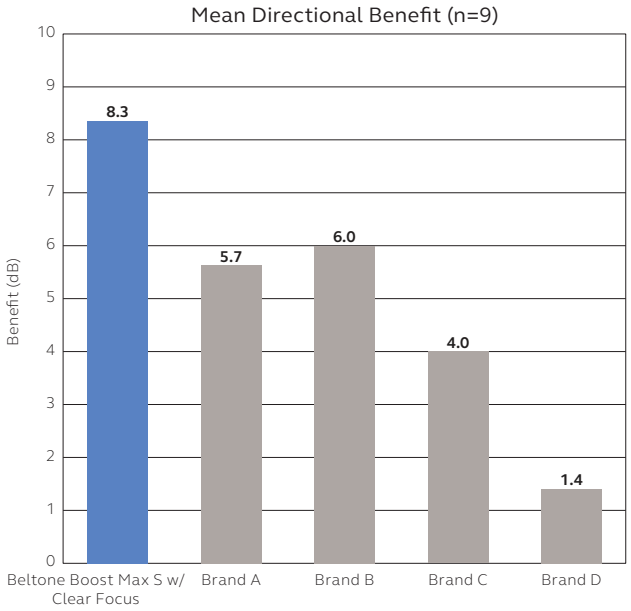


Figure 3. Test participants' mean directional benefit with Beltone Boost Max S and SP BTE hearing aids from four other premium hearing aid brands.

Study 2: Sound Quality Preference

The sound quality preference study was carried out using the SenseLabOnline test system from Force Technology which has become the de facto standard for sound quality evaluation within the hearing aid industry. When using SenseLabOnline the test participants evaluate their sound quality preference by listening to different sound recordings under headphones and selecting the one they prefer. The SenseLabOnline test system offers double blinding and eliminates multiple other sources of bias.[8,9]

Methods

Participants

Six test participants were selected for the sound quality preference evaluation. The 2 female and 4 male participants had a median age of 80 years with a 1st quartile of 64 years and a 3rd quartile of 84 years. They all had bilateral severe-to-profound sensorineural hearing loss and were experienced hearing aid users with a median of 28 years of experience with amplification (1st quartile of 20 years and a 3rd quartile of 45 years). The participants were all current users of premium High-Power or SP BTE hearing aids from different hearing aid brands.

Test conditions, material, and setup

A pair of rechargeable Beltone Boost Max S SP BTE hearing aids as well as a pair of legacy Beltone Boost Ultra SP BTEs were used for the sound quality preference study. The hearing aids were fitted with gain prescribed to an N5 audiogram[10] for experienced hearing aid users, using the proprietary BAFA fitting rationale. The two pairs of hearing aids were each fitted with the default hearing aid program 1: "All-Around" and program 2: "Hear in Noise".

The All-Around program contains the CrossLink Directionality 4 feature in Beltone Boost Max S and the legacy CrossLink Directionality 2 with Personal Sound ID in Beltone Boost Ultra. While both programs are based on the same rationale of supporting native listening strategies, CrossLink Directionality 4 uses ear-to-ear streaming to achieve 4-microphone binaural beamforming in the directional microphone modes. The legacy CrossLink Directionality 2 relies on device independent dual microphone fixed directionality.

The Hear in Noise program contains the Clear Focus feature combination consisting of an upgraded 4-microphone beamformer and Sound Cleaner Pro single channel noise reduction in Beltone Boost Max S and the feature combination Smart Beam and Sound Cleaner Pro noise reduction in Beltone Boost Ultra. Clear Focus differs from the 4-microphone beamforming in CrossLink Directionality 4 in that it applies the directionality over a wider bandwidth (see Jespersen et al, 2025[11] for further details). The test conditions were:

Test condition	Device	Directionality feature
All-Around Program	Beltone Boost Max S	CrossLink Directionality 4
	Beltone Boost Ultra	CrossLink Directionality 2
Hear in Noise program	Beltone Boost Max S	Clear Focus
	Beltone Boost Ultra	Smart Beam

Table 1. Hearing aid program conditions for the two hearing aids in the test.

The sound quality of the All-Around and Hear in Noise programs in the Beltone Boost Max S and Beltone Boost Ultra hearing aids was evaluated by having different sound scenes played over loudspeakers and recorded through all four hearing aid program conditions as specified in Table 1. The recordings were then played to the test participants over headphones in a randomized order.

There were 5 sound scenes with one being live recorded alternating male and female speech with a concatenation of 10 utterances from Dantale II in quiet. Another scene was music. Three sound scenes were combined speech and background noise. The speech was alternating male and female speech with concatenation of 10 utterances from Dantale II including increased vocal effort (=Lombard effect) as people tend to increase their vocal effort when in background noise.[12-15] The background sound scenes were selected to be representative for different hearing aid user environments, and they were selected from the FORCE Higher-Order Ambisonics Sound Scene Repository database which is a database containing various 3D real life sound scenes.[12] The sound scene recordings are shown in Table 2.

The binaural recordings were made at ecologically valid SNRs to simulate real-life conversations. In real life, conversations mostly happen at positive SNRs, because speakers adapt their vocal effort and distance to the listener when noise is present.[12-15] An additional consideration is that we wanted participants to focus on quality and preference, not on speech understanding per se.

Sound scenario	SPL(A)	Speech SPL (A)	SNR (A)
Male and female speech in quiet	-	65 dB	-
Music: Beautiful Day with U2	-	-	-
Male and female speech with Lombard effect in car	67 dB	72 dB	5 dB
Male and female speech with Lombard effect in car	70 dB	75 dB	5 dB
Male and female speech with Lombard effect in car	68 dB	73 dB	5 dB

Table 2. The sound recordings, levels and SNRs used in the Sound Quality Preference Study. "SPL(A)" denotes the level of speech in the sound scenario. There was no speech added to the Music scenario which is why SPL (A) is not reported.

The 5 sound scenes were recorded through the All-Around and Hear in Noise programs of the two test hearing aids while the hearing aids were placed on a Head and Torso Simulator (HATS 5128-C) using Comply tips. The sound scene played for 60 seconds prior to starting the recording to ensure that the hearing aid features had adapted fully to the sound scene prior to making the recording. HATS was placed in the center of GN's 3D anechoic laboratory, which contains 49 loudspeakers placed in a sphere and 4 subwoofers and with access to the 5 sound scenes listed in table 2. The 5 sound scenes were played back to achieve a diffuse sound scene reproduction. The diffuse sound scene recordings through the hearing aid programs were shortened to 15 seconds for playback to the test participants.

The sound quality preference evaluation was done using the SenseLabOnline software interface. This allows the test participants to listen to the recordings in a randomized double-blind way. They listened using Sennheiser HD650 headphones while sitting in a quiet fitting room. The test participants were instructed prior to the evaluation both in writing and verbally to ensure a correct understanding of the task.

Results

The preference for the All-Around and Hear in Noise programs in Beltone Boost Max S and Beltone Boost Ultra is shown in Figure 4. The preference results are shown for the 5 sound scenes combined due to the low number of test participants. Binomial statistical tests were used to determine whether the Beltone Boost Max S All-Around and Hear in Noise programs were preferred over the Beltone Boost Ultra All-Around and Hear in Noise programs. The participants preferred The Boost Max S All-Around program over the legacy Beltone Boost Ultra All-Around program in 27 of the 30 tests ($p<.001$) or 90% of the time. They preferred the Beltone Boost Max S Hear in Noise program over the Beltone Boost Ultra Hear in Noise program in 28 of the 30 tests ($p<.001$) or 93% of the time.

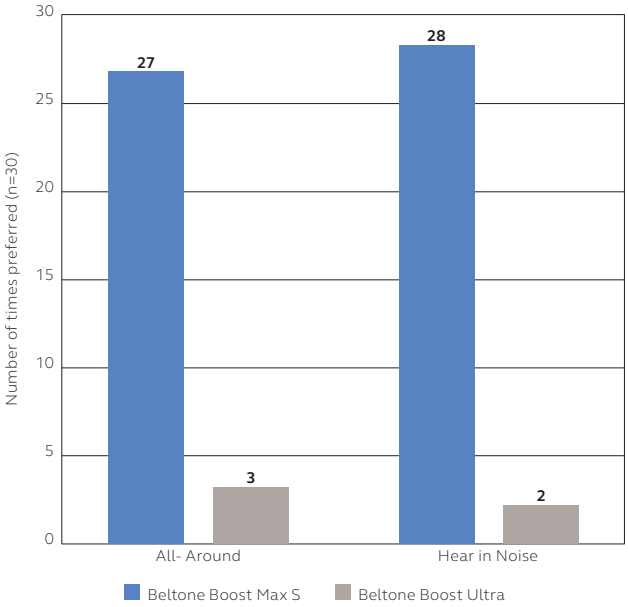


Figure 4. Sound quality preferences for Boost Max S and Boost Ultra in the All-Around program and Hear in Noise program. Six test participants made 5 sound quality preference judgments each, resulting in 30 total judgments per condition.

Conclusions

Compared to the legacy solution, the upgraded technologies of Beltone Boost Max S offer clear benefit that is readily demonstrated:

- People with severe-to-profound hearing loss show a strong preference for the All-Around and Hear in Noise programs in Beltone Boost Max S over the corresponding programs in Beltone Boost Ultra.
- Directional performance of the upgraded 4-microphone binaural beamformer available in Beltone Boost Max S provides a significant mean directional benefit of 8.3 dB SNR, which exceeds that provided by legacy Beltone Boost Ultra by 2.7 dB.
- Directional benefit of 4-microphone beamforming in SP BTEs across brands is significantly better than device independent 2-microphone directionality.

These findings underscore the importance of advanced technology along with fitting flexibility, and user-centric design in hearing aids for individuals with severe-to-profound hearing loss. By focusing on these elements, Beltone Boost Max S aims to significantly enhance the quality of life for its users, enabling them to engage more fully in their daily activities and social interactions. Overall, these advancements reflect a commitment to addressing the unique challenges faced by individuals with the most severe hearing losses.

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Worldwide Headquarters
Beltone A/S
Lautrupbjerg 7
DK-2750 Ballerup
Denmark
Tel.: +45 4575 1111
beltone.com

CVR no. 55082715

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