Keeping the Conversation in Front: A Combined Spatial–Denoising Approach to Managing Multi-Talker Noise

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Abstract

Hearing aids that apply advanced denoising technology in their automatic program may inadvertently interfere with users' listening goals by spotlighting unwanted speech. In contrast, True Directionality relies on the powerful AcoustIQ™ environmental classification and control system to deploy directionality, denoising, as well as other technologies in a way that supports and empowers users to hear their best across their daily listening situations. We carried out a study to quantify the consequences of different approaches to how denoising technology is applied. Listeners were fitted with hearing aids from another premium brand and Beltone Illuminate. Both products have a denoising feature that is available in both their automatic program as well as a user selectable program. In a controlled multi talker in noise scenario with a target talker in front and a distractor talker to the side, we asked the listeners to identify which talker was more audible. The results showed that 80% of listeners could hear a target talker better than a distracter talker with the Beltone feature compared to the other brand's, providing evidence that the way denoising is implemented in the automatic program can help or hinder their listening experience. The data illustrate why targeting the most probable intended talker in complex environments is essential for delivering a more natural and less fatiguing listening experience.

In everyday life, listeners constantly move between acoustic situations that differ in complexity, competing sounds, and demands on attention. A successful hearing aid must therefore do more than simply amplify speech; it must support the user's intuitive listening strategies as they navigate from quiet one-to-one conversations, through moderately complex social settings, to highly complex multi-talker environments. Today's hearing aids have many features, including directional microphones and different types of noise reduction, that can help users communicate better in their daily environments. By automating the application of such features in a default listening program intended for common listening situations, hearing aids can provide benefits of advanced features without the need for users to understand how they work or to recognize when to manually apply them. For an automatic program to work optimally, the hearing aids must be driven by a system that fulfills the following requirements:

- Analyses the listening environment in a way that corresponds to human perception, and consequently controls the application of features to provide benefit in those environments;
- Provides transparent transitions as the environment changes to avoid jarring or noticeable changes in the experienced sound;
- Streamlines application of power-consuming technologies to ensure stable performance and maximal battery life.

Upgraded technology introduced in Beltone Illuminate is designed exactly to meet these challenges. Similar to previous generations, transparency in transitioning among the application and strengths of different features is particularly dependent on providing an omnidirectional response in the low frequencies even when directional microphones are active. This approach carries over from legacy products to Beltone Illuminate to ensure rich sound quality in all listening modes. The AcoustIQ environmental classification and steering system quickly and accurately characterizes the acoustic environment and controls features according to a rationale based on how listeners naturally try to hear in various types of listening situations. Briefly, this rationale switches among three modes that support innate listening strategies, thereby respecting listener intent and leaving the hearing aid user in control

of what they want to focus on (see Jespersen et al[1] for a discussion of this rationale). In the Beltone Illuminate 17, AcoustIQ is the brain behind the automatic True Directionality program. This program maintains sound quality and awareness in quiet, gives focus to the primary conversation in moderate noise while still allowing access to the surroundings, and provides stronger support in complex situations where multiple talkers and noise sources compete. While the Beltone environmental classification has previously been shown to identify sound scenes with near-perfect accuracy,[2] results with AcoustIQ further demonstrate equally high accuracy in applying features according to evidence-based expectations in the True Directionality program – up to 88% more accurate than the application of features in the automatic programs of five other premium hearing aid brands.[3]

Complex listening situations are where hearing aid users often experience the greatest frustration - and where many current hearing aid solutions fall short. In these environments, noise can be much more than just a tiring mélange of different sounds; there may be other talkers whose speech is intelligible enough to be distracting, but not relevant enough to be the talker the listener wants to follow. Beltone offers users a manually selectable "Hear in Noise" program as one way to address this challenge. The Hear in Noise program provides immediate and noticeable help in any situation where they want to focus on speech in front of them and gives them extra control of their listening experience. In our most advanced technology, this program deploys True Focus, which combines our strongest 4-microphone directional beamforming with a highly efficient Deep Neural Network (DNN) based denoising algorithm. The DNN denoising in True Focus is 17 times more efficient than that of another leading brand.[4] This means that battery drain does not pose a limitation in how often it can be used. More importantly, Intelligent Focus was preferred by 89% of users for listening in noise compared to legacy noise reduction technology.[4]

With AcoustIQ, we can now apply strong beamforming with low frequency omnidirectional processing, along with denoising automatically in our True Directionality program. This increases the benefit of this technology to users in even more situations as they will experience it even without manually selecting another program. The goal is not only to improve signal to noise ratio (SNR) per se, but to reduce the subjective distraction from interfering talkers while preserving access to the talker that the listener is most likely trying to attend to. A real life story illustrates what is at stake when this is not done correctly. One of our trial participants owns hearing aids from another premium brand with denoising integrated in its automatic program. She described arriving at her busy home airport and being met by her granddaughter. At the same time, a group of football players was also entering the arrivals hall, chatting loudly together. As she approached her granddaughter, the girl was eager to greet her and tell her something. Unfortunately, the decision-making in the lady's hearing aids caused them to focus on one of the louder football players off to the side rather than her granddaughter's voice in front, and she struggled to hear what her granddaughter said. The result was a highly distracting listening experience in exactly the kind of complex situation where she most needed help.

This example highlights a fundamental limitation of denoising strategies that simply prioritize the loudest talker in the vicinity. Loudest does not necessarily mean most important, and in many real world scenarios the intended talker is predictably the person in front, even if other voices are closer or louder. Therefore, in complex, very noisy listening situations, our automatic program engages denoising in a way that supports the intuitive strategy of "keeping the conversation in front." Instead of blindly following the loudest voice, it is designed to favor the most probable intended talker relative to the listener's position and focus, while reducing the salience of interfering talkers who are not in front.

We designed a study to quantify the consequences of these different approaches. Listeners were fitted with hearing aids from another premium brand—whose automatic program with denoising focuses on the loudest nearby talker—and with Beltone Illuminate 17 hearing aids where our automatic program uses denoising tuned to support listening to the likely intended talker in complex listening situations. The objective was to evaluate both systems in terms of audibility of a target talker versus an off-axis distractor talker in a simulated realistic complex listening scenario.

Method

Participants

Twenty test participants (5 females and 15 males) with sensorineural hearing loss and with a word recognition score between 80 and 98% participated in this study. The median age of the participants was 78 years with a 1st quartile of 69 years and a 3rd quartile of 81 years. The participants were all current users of premium Receiver-in-the-ear (RIE) hearing aids from different hearing aid brands. The participants had a median of 10 years of experience with amplification with a 1st quartile of 4 years and a 3rd quartile of 18 years.

Hearing aids and fitting

Each participant was fitted with a pair of Beltone Illuminate 17 RIE hearing aids as well as the most current RIE hearing aids with denoising from another premium hearing aid brand (Brand A). The hearing aids were fitted with each hearing aid brand's default gain prescription for experienced hearing aid users combined with each brand's most occluding domes to maximize the effect of the signal processing. Because the goal of the study was to fairly compare the effects of applying the denoising and related technologies and not to evaluate whether the control algorithm provided accurate switching to those settings, we programmed the hearing aids with each brand's expected settings for the given listening environment instead of using the automatic program. In both cases, this included directionality combined with the denoising feature. The test order of the two pair of hearing aids was randomized and the test participants were blinded to which hearing aids they were evaluating.

Test material and setup

Test setup

A simulated real-world scenario in a sound booth was used for the test. An array of four loudspeakers that played background noise formed a square inside the sound booth. One additional loudspeaker used for the target talker was placed at 0° azimuth and 120 cm from the participant. A loudspeaker at -90° azimuth was used for the distractor talker (see figure 1). All loudspeakers were positioned at a height of 120 cm above the floor.

The scenario had a target male talker at 65 dB SPL that was played from 0° azimuth and a distractor female talker at 70 dB SPL that was played from -90°. There was also diffused babble noise at 60 dB SPL around the test participant.

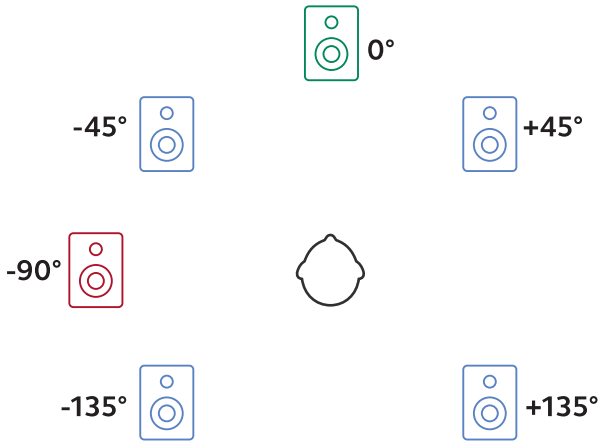


Figure 1. Illustration of the placement of the target talker (green) and distractor talker (red) as well as the placement of the babble noise (blue).

Test material and task

The babble noise consisted of a 4th order Ambisonics recording of multiple English-speaking talkers providing a cocktail-party effect listening situation. The recording was decoded for playback over the square loudspeaker arrangement in a sound booth, with one loudspeaker for each of its corresponding vertexes. The participant was seated at the center of the test setup.

The target and distractor talker stimuli were taken from a GN database with recordings at different voice-effort levels to account for the Lombard effect in a noisy environment. Recordings labeled as “Mid effort” were used for both target and distractor.

The babble noise together with the target and distractor talker was played for at least 40 seconds to give the hearing aids’ adaptive algorithms time to adapt to each sound scene. Following the 40 second adaptation time, the test participants were asked to evaluate which voice - the target talker or the distractor talker - had the best audibility.

Calibration

Continuous equivalent sound pressure level (Leq) measurements were carried out with the sound level meter placed at the participant position at 120 cm height, and with no weighting applied. Each stimulus was played for approximately 40 seconds, which allowed the Leq to stabilize.

The background noise was calibrated without further manipulation of the audio files. For the speech calibration, the audio files were edited to remove the gaps between the sentences, resulting in continuous speech. The level was adjusted in the corresponding track of the Digital Audio Workstation (DAW) until the Leq measurement corresponded with the desired SPL.

Equipment

The test was conducted at the GN Hearing facilities in Ballerup. Audio was presented from Genelec 8331A loudspeakers, and sound levels were measured using a B&K 2270 sound level meter in combination with a B&K 4189 microphone. A B&K 4231 acoustic calibrator was used for level calibration of the sound meter. Audio playback was controlled from a PC where Reaper (v7.62) was used as the DAW.

Statistical analysis

The preference data was analysed using an exact binomial test.

Results and discussion

Sixteen participants (80%) indicated better audibility of the target talker than the distractor talker when listening with Beltone Illuminate compared to 4 participants (20%) when listening with premium hearing aids from Brand A.

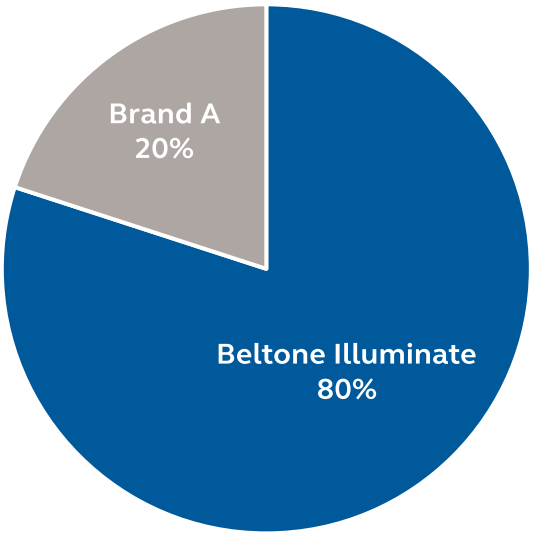


Figure 2. The percentage of the 20 participants who reported better audibility of target talker in a sound scene with an off-axis distractor talker for each of the two hearing aid brands.

The results of this study reinforce the rationale for adding denoising specifically to the complex situation mode of our automatic program and for designing it to support intuitive listening strategies rather than simply maximizing the level of the nearest or loudest voice. When listeners were fitted with the other brand's hearing aids, whose automatic denoising locks onto the loudest nearby talker, most of them perceived the interfering talker as being most audible. In contrast, with our hearing aids, which combine the automatic program and denoising tuned to favor the most probable intended talker in front, most listeners experienced less distraction from the competing talker and could focus more effectively on the target speech.

It should be noted that in this study we did not ask the participants to assign a judgment to the sound they experienced with each of the hearing aids tested. The task was not to tell us directly that the off-axis talker was interfering or distracting. Rather, they indicated which of the two talkers was most audible. The reason for approaching the study in this way was that the results could provide us with a non-biased explanation for an earlier finding where these technologies were compared in terms of speech recognition in divided and selective attention tasks.[5] In the earlier study, listeners tried to locate and attend to a target talker in a speech-on-speech background where the target talker either did (divided attention) or did not (selective attention) change location. While there were no significant differences among the three hearing aids tested for the divided attention task, performance was significantly better with strong directionality combined with Intelligent Noise Tracker than with the directionality and denoising applied by Brand A for selective attention. It was inferred that the increased performance was related to increased audibility of non-target talkers with Brand A relative to the Beltone technology, and the results of the current study support this idea.

Despite not specifically asking participants to rate or judge how difficult it was to hear the target talker or how distracting the off-axis talker was, several participants spontaneously commented that the Beltone Illuminate hearing aids (they were blinded as to which hearing aids they were wearing) made the target talker clearer and easier to hear. Typical comments included:

"The target feels easier to hear"
"Listening to the target speaker requires less effort"
"The distractor is much less prominent"
"I can hear the man a bit better and clearer"
"The target is more prominent and clear"

Viewed in light of the story we related about the lady who wanted to greet her granddaughter in the airport, these findings highlight a central challenge of real world hearing: the most important talker is not always the loudest or closest. Our approach for the automatic program is to identify the acoustic conditions and then deploy technologies in a way that aligns with how listeners intend to listen. In relatively quiet conditions, listeners rely on access to spatial cues and place high value on sound quality. A bilateral omnidirectional or pinna compensation response makes the most sense to meet these needs. In moderately complex, noisy environments, it is difficult for hearing aid systems to decide with a high degree of certainty where the sound of interest is. Therefore, users get a directional response on one ear, and an omnidirectional response on the other, allowing their brains to take advantage of the ear with the best SNR for what they want to hear. Conversely, in complex situations, listeners naturally orient to the conversation in front and try to suppress competing talkers elsewhere. A denoising system that enhances the loudest voice can work against this listening strategy, effectively "handing over control" of the hearing aid to whichever talker happens to dominate the sound field. Our results support that this can increase distraction and undermine listening comfort.

Taken together, cumulative results of studies comparing the commercially available denoising features suggest that our approach better supports real world communication goals in demanding environments. In practical terms, this means that users are more likely to experience their hearing aids as "on their side" in situations like the airport arrival hall - helping them keep the conversation in front instead of amplifying the voices they are trying to ignore.

Conclusion

Listeners reported better audibility of a target talker with Beltone Illuminate over the other hearing aid brand (brand A) in a listening environment with background noise and more than one talker.

Spontaneous comments from participants about their experience listening with the two hearing aid brands tested lend credibility to the idea that our most powerful noise management provides clarity of desired speech with reduced effort.

This study joins a longstanding body of evidence showing how our philosophy of product development leads to advanced hearing solutions that leverage natural hearing processes and behaviors, allowing hearing aid users to use their hearing in a natural way.

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