Phonak Compendium

StereoZoom Part 1: The benefit of wirelessly connected narrow directionality in Phonak hearing aids for speech intelligibility

A primary solution for improving listening in noise is the use of directional microphone technology. In the first of a 3-part series examining the value of narrow directionality in Phonak hearing aids for listening in noise, benefits for speech understanding will be presented, with particular emphasis on performance improvements provided by the adaptive narrow beamformer, StereoZoom. Future installments of this series will discuss further advantages of StereoZoom, including reduced listening effort and enhanced social engagement, as well as the scope of its application across client groups.

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Introduction

Understanding speech in the presence of background noise is one of the most difficult tasks for individuals with sensorineural hearing loss, even when wearing appropriately-fit hearing aids. In complex, noisy environments, hearing aid users require a more favorable signal-to-noise ratio (SNR) than their normal-hearing peers to achieve the same level of performance (e.g., Killion, 1997). Further, the ability to understand speech in noise has been found to predict hearing aid satisfaction. According to MarkeTrak IX, the most satisfied hearing aid users feel their hearing aids successfully minimize background noise, are comfortable to wear when listening to loud sounds and improve the ability to tell the direction of where sound is coming from (Abrams & Kihm, 2015).

Over the last several decades, hearing aids manufacturers have implemented increasingly advanced noise reduction technologies to improve SNR and consequently enhance speech recognition. One of the most commonly used noise reduction technologies in hearing aids is known as beamforming, which involves the use of two microphones operating in tandem to allow the hearing aid to produce a directional signal and thus act as a 'spatial noise canceller'. Since it is typical for the signal of interest to be in front of the hearing aid user and unwanted background noise to come from behind, this microphone setup is designed to improve speech understanding, even with background noise present. That is, beamforming allows the hearing aid to be more sensitive to sounds coming from the front and attenuate sounds coming from the back. With these early directional microphone systems, SNR was found to improve by as much as 6 dB, relative to unaided hearing, in cases of slightly sloping to severe hearing loss (Lewis et al., 2004).

In Phonak receiver-in canal (RIC) and behind-the-ear (BTE) hearing aids, a low-strength beamformer, called Real Ear Sound (RES), mimics the directional benefit provided by the shape and resonances of the pinna. As listening environments become more difficult, however, stronger directivity is necessary to maintain performance.

With the Spice platform, Phonak introduced a two-directional monaural adaptive beamformer, UltraZoom (UZ), to further improve SNR. UZ is designed to create a narrower beam compared to that produced by RES in the front hemisphere (with respect to the hearing aid wearer). The position of the null is adaptively varied in the back hemisphere to maximize the SNR benefit. UZ has been shown to significantly increase the SNR and improve speech recognition relative to RES for hearing aid listeners in both diffuse and localized noisy listening conditions (Ebbing & Omisore, 2015).

A monaural directional processing system, however, has limitations. As noise becomes increasingly more diffuse, a monaural system with two microphones on each hearing aid may not be effective in separating the sources of noise from the target sound source. The relatively wide beam picks up sounds – both signal and noise – from the front, which arrive at the microphones from multiple directions within the beam at the same time. The performance of a beamformer can be significantly improved by increasing the number of microphones that are used to produce the beam, allowing for the formation of an even more narrow beam. This results in a more favorable SNR and helps the hearing aid user achieve improved speech recognition in a diffuse noise situation. Due to the size limitations of hearing aids, the ability to build additional microphones into each individual hearing aid was not feasible in the existing form factor. With the advent of binaural communication in Phonak devices, however, it was possible for the hearing aids to share the output of the monaural beamformer between the two hearing aids, creating a bidirectional network of four microphones. This feature is referred to as Static StereoZoom (SSZ), first introduced in Phonak Quest hearing aids. Assuming the target signal – often a single talker – is directly in front of the hearing aid user, a focused beam produced by the SSZ microphone configuration will amplify the voice of the desired talker exclusively and attenuate all others.

The "new" StereoZoom (SZ) program, first introduced by Phonak on the Venture platform, improved upon SSZ by incorporating a variable null that adapts according to the location of the noise source(s) relative to the hearing aid user. This feature retains the SNR benefit in diffuse noise provided by SSZ, while incorporating the advantage of a variable null provided by UZ – namely, reducing localized and lateralized noise sources. The combined effect of a narrower beam and an adaptive null location allows the hearing aid to maximize speech recognition in the presence of diffuse as well as localized noise sources.

StereoZoom is available on the new Marvel hearing aid platform, along with a number of new innovations. This hearing aid is the first in the industry to be Bluetooth compatible with both Android and iPhones. In addition to superiority in Bluetooth streaming capability, Marvel maintains the superior performance in background noise delivered by previous Phonak platforms through the application of binaural directionality. The SZ microphone mode is applied in the Speech in Loud Noise (SPiLN) program, one of the programs available in AutoSense OS, the automatic classification system in Phonak hearing aids. SPiLN is activated automatically in Premium performance level technology when a threshold signal-to-noise ratio is reached and maintained. The SPiLN sound class may be added as a manual program in mid-level devices.

Previous studies of directional microphone technology, including SZ, have consistently demonstrated improved speech intelligibility in background noise. The findings of these studies are summarized and described here, and in Table 1.

The benefit of a binaural beamformer has been demonstrated in numerous research studies since their implementation in hearing aids. SZ takes the traditional binaural beamformer a step further, as it adapts to the surrounding environment, while maintaining a narrow beam that is characteristic of the binaural beamformer. Several key research studies have demonstrated the substantial benefit SZ can provide in various degrees and types of background noise.

Author	Subjects	Speech test	Outcome measure	Test setup	Conditions tested	Results
Appleton & König, 2014	N= 20 subjects with mild-mod, mod-severe HL	OLSA	SRT in dB	Setup 1: Babble noise from 30 to 330 degrees; speech from 0 degrees Setup 2: Babble noise from 90 and 270 degrees; speech from 0 degrees	1. Omnidirectional 2. UZ 3. SSZ 4. SZ	Setup 1: SZ 3.5 dB benefit over omni**, .5 dB benefit over SSZ,1 dB benefit over UZ Setup 2: SZ 5.5 dB benefit over omni**, 1.5 dB over SSZ**, 1 dB over UZ
Ebbing and Omisore (2015)	N= 10 BiCros Users	OLSA	SRT in dB	Cafeteria noise from 90 and 270 degrees, speech from 0 degrees	1. Quest CROS 2. CROS II with UZ 3. CROS II with SZ	Average improvement of 3.8 dB with CROS II with SZ as compared to CROS II with UZ
Latzel & Appleton-Huber, 2015	N= 20 subjects with mod to severe HL	OLSA	SRT in dB	Setup 1: Babble noise from 30 to 330 degrees; speech from 0 degrees Setup 2: Babble noise from 90 and 270 degrees; speech from 0 degrees	1. UZ 2. SSZ 3. Binaural BF competitor 1 4. Binaural BF competitor 2 5. SZ	Setup 1: SZ 1.5 dB benefit over UZ*, 2 dB benefit over competitor 2** Setup 2: SZ 2.5 dB over competitor 1*, 2 dB benefit over competitor 2*, 1.5 dB benefit over SSZ*
Stuermann (2011)	N= 8 subjects with mild HL	OLSA	SRT in dB	Cafeteria noise from 60, 120, 180, 240, and 300 degrees; speech from 0 degrees	1. Unaided 2. UZ 3. SZ	Average 2.5 dB over unaided**, 1 dB benefit over UZ
Picou et. al (2014)	N= 18 Subjects with mod to mod-severe HL	Connected Speech Test (CST)	Sentence Recognition Performance (RAU)	Four uncorrelated samples of CST multi-talker babble from four loudspeakers: 45, 135, 225, 315. Sentences from 0 degrees.	1. "Mild" RES 2. "Moderate "UZ 3. "Strong" SZ	In moderate reverberation, performance with strong directional processing (SZ) was better than mild (RES) or moderate (UZ) directional processing**.
Latzel & Appleton-Huber (2018)	N =12 subjects with severe hearing loss	OLSA	SRT in dB	Street noise from 30, 60, 90, 270, 300, 330 degrees; speech from 0 degrees.	1. RES 2. UZ 3. SZ	Average 2 dB improvement with SZ as compared to RES**, and 0.4 dB compared to UZ.

Table 1: Summary of studies related to the effectiveness of StereoZoom (SZ). UZ = UltraZoom, SSZ = Static StereoZoom, RES = Real Ear Sound. * = significance at a p-value of .05, ** = significance at a p-value of .01, *= significance at a p-value of 0.002,**

SZ has been shown to yield better performance on measures of speech intelligibility relative to other beamforming technology available in Phonak devices, as well as competitor hearing aids (Latzel & Appleton-Huber 2015; Appleton & König, 2014). In a study of 20 individuals with mild to severe hearing loss, speech understanding in noise was assessed using the three beamforming approaches discussed above (UZ, SSZ, SZ; Appleton & König, 2014). Performance in each directional mode was calculated relative to performance in the omnidirectional mode to quantify the benefit of each model of beamforming. Testing was completed in two noise conditions: (1) *diffuse noise*, with speech presented from a single speaker at 0° azimuth, and cafeteria noise presented from 11 speakers positioned at 30-330° azimuth; and (2) *lateralized noise*, with speech from the front (0°) and cafeteria noise presented only from the sides (90° and 270°). Results revealed that binaural beamforming (SSZ, SZ) yielded a greater improvement in speech intelligibility in diffuse noise, relative to the omnidirectional condition, compared with the monaural beamformer (UZ). In the lateralized noise condition, SZ showed a greater performance benefit relative to UZ, while speech intelligibility benefit in SSZ was equivalent to that of UZ (Appleton & König, 2014). This same procedure was used in a follow-up study of 20 adults with moderate to severe hearing loss (Latzel & Appleton-Huber, 2015). Again, speech recognition in noise was assessed using UZ, SSZ, and SZ, as well as adaptive beamformers from two different competitor hearing aids. As in the previous study, performance in each program was calculated relative to performance in an omnidirectional microphone mode to determine the benefit of each beamformer for speech-in-noise. In the diffuse noise condition, SZ showed greater benefit compared to UZ and to one of the competitor technologies. In lateralized noise, SZ outperformed all other beamformers (Latzel & Appleton-Huber, 2015).

An external study conducted at Vanderbilt University investigated the effectiveness of three types of directional processing (mild, moderate, strong) for various listening tasks, including sentence recognition (Picou et al., 2014). Mild directional processing was similar to that of an omnidirectional microphone, with additional processing to emulate the acoustic benefits of the pinna (RES). Moderate directional processing consisted of a monaural directional beamformer (UZ), while the strong condition was an adaptive binaural beamformer (SZ). Eighteen adult listeners with moderate to severe hearing loss were tested in each of the three directional processing conditions. To assess speech recognition, participants repeated as many words as they could understand from lists of high-context sentences. This task was scored in percent correct on key words. Sentence recognition was completed in "easy" (more favorable SNR) and "hard" (poorer SNR) listening conditions. Precise SNRs tested were participant-specific, depending upon performance, so as to avoid floor and ceiling effects. Performance was significantly better with strong and moderate directional processing compared to mild directionality in both favorable and poor SNRs (Picou et al., 2014). Taken together, these studies demonstrate that SZ successfully addresses the need for an improved SNR for speech understanding, and therefore better speech understanding in noise. These findings suggest that when StereoZoom is activated by AutoSense OS in the most challenging listening environments, it provides an "extra gear" of signal processing precisely when it is needed.

Conclusion

Speech understanding in noise is one of the most challenging listening situations for individuals with hearing loss, and is one of the most fundamental aspects for hearing aid satisfaction (Abrams & Kim, 2015). Through a process of continuing innovation, Phonak has provided incremental improvements in technologies designed to optimize speech understanding in noise. Narrow directionality using a four-microphone network across the two hearing aids provides a higher input SNR to the listener, with more focus on the signal of interest in front of the listener and attenuation of signals arriving from behind. The most advanced beamformer offered by Phonak, StereoZoom, has improved directional processing even further than previous directional microphones by making this narrow beamformer adaptive. This enhanced directionality improves attenuation of background noise and provides more favorable SNRs compared to a monaural adaptive beamformer and a static binaural beamformer, two previous Phonak beamformer configurations. The research presented here establishes the benefit of StereoZoom for improving speech intelligibility.

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