WHITE PAPER

Binaural OneMic Directionality 2.0 delivers 5 times the speech enhancement in noise versus key competitors

Improving speech clarity in noisy environments is essential for enhancing hearing aid wearer satisfaction. Applying directionality in hearing aids is widely recognized as the most effective method of improving the signal-to-noise ratio and enhancing speech-in-noise clarity. Signia's unique Binaural OneMic Directionality (BOMD) 2.0 technology makes Signia the only manufacturer capable of delivering directionality in single-microphone hearing aids – enabled by the low-latency, wide-bandwidth ear-to-ear communication (e2e 4.0) offered by the Signia Integrated Xperience (IX) platform. In this white paper, we present two studies that assess the technical and human performance delivered by BOMD 2.0. The first study demonstrated that BOMD 2.0 delivers five times the speech enhancement in noise compared to key competitor CIC hearing aids that can only offer an omnidirectional response. The second study confirmed that the directional benefit provided by BOMD 2.0 translates directly into a significant improvement in the wearer's ability to understand speech in noise. Together, the results provide clear evidence of the benefits of BOMD 2.0 technology, available in all single-microphone Signia IX hearing aids. BOMD 2.0 technology empowers hearing care professionals to deliver exceptional speech-in-noise performance to their clients, without compromising on the discreet CIC fit valued by many wearers.

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Take-away messages

- Signia's exclusive Binaural OneMic Directionality (BOMD) 2.0 uniquely delivers directionality in single-microphone hearing aids, while all major competitors remain limited to basic omnidirectional responses in noise.
- BOMD 2.0 technology is enabled by the unique low-latency, wide-bandwidth ear-to-ear communication (e2e 4.0) provided by the Signia Integrated Xperience (IX) platform.
- BOMD 2.0 delivers five times the speech enhancement in noise compared to key competitors, due to a 7 dB improvement in directional benefit.
- Activation of BOMD 2.0 provides a significant improvement of speech understanding in noise.

Introduction

In challenging listening environments, such as dynamic social gatherings or noisy public spaces, understanding speech can be difficult for individuals with hearing loss (Picou, 2022). Directional microphone technology has long been recognized as a key method to improving speech understanding in noise by enhancing sounds from the direction of the speaker while suppressing background noise (Bentler, 2005).

Hearing aids with dual microphones (i.e., two microphones per hearing aid) achieve directional benefits through beamforming techniques that utilize the physical distance between the two microphones to create directional beams (i.e., enhancing sounds from certain directions and suppressing sounds from other directions) by combining the two microphone signals in specific ways. However, traditional directionality has not been feasible in smaller hearing aids, such as Completely-in-Canal (CIC) models, as their ultra-compact design allows space for only a single microphone. This size constraint has historically prevented the inclusion of directional capabilities in discreet, single-microphone hearing aids.

Signia has consistently been seen as a leader in hearing aid innovation, not least when it comes to directionality, and in particular binaural beamforming, i.e., directionality based on binaural signal processing where audio signals are transmitted between the left and right hearing aids.

Binaural OneMic Directionality (BOMD) technology represents a major advancement in the field, overcoming inherent constraints by leveraging advanced binaural processing to enable a virtual directional microphone system from two single-microphone hearing aids.

While binaural beamforming is offered by other manufacturers for dual-microphone hearing aids (using a 4-microphone array), Signia's BOMD technology remains unique in the hearing aid industry. No other manufacturer offers single-microphone hearing aids with directionality and the associated wearer benefits using a 2-microphone array.

With the introduction of the Signia Integrated Xperience (IX) platform, an updated version, Binaural OneMic Directionality 2.0, was released. BOMD 2.0 benefits greatly from the technical improvements of the IX platform, particularly the e2e 4.0 binaural link.

BOMD 2.0 technology is available in all Signia IX single-microphone form factors – Silk Charge&Go IX, Insio IIC / CIC IX, and Insio Charge&Go CIC IX – offering the same performance and wearer benefits for all form factors. Therefore, this paper will focus on the BOMD 2.0 technology across the different form factors. We present results from two studies — one evaluating the technical performance, and another evaluating the human performance provided by the technology. Before describing the studies and presenting the results, we provide a brief technical overview of BOMD 2.0.

Binaural OneMic Directionality 2.0

A key element in BOMD 2.0 is Signia's proprietary low-latency, wide-bandwidth ear-to-ear communication system, e2e 4.0. This binaural link enables instantaneous and continuous synchronization and audio transmission between the two hearing aids.

Each hearing aid captures sound via its single microphone, and by sharing and synchronizing acoustic information between the left and the right hearing aids in real time, the system functions as a virtual directional 2-microphone array, which offers beamforming in both hearing aids, as illustrated in FIGURE 1.

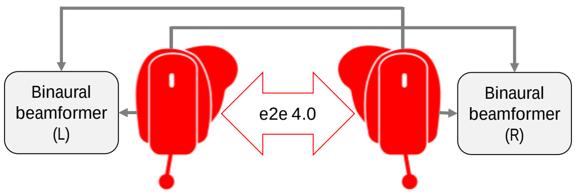

FIGURE 1 The e2e 4.0 binaural link is the key enabler of Binaural OneMic Directionality 2.0. Audio signals from the two microphones are combined and processed in both the left and right hearing aid to offer binaural beamforming.

Advanced signal processing algorithms analyze interaural differences in sound level, time and phase cues to distinguish target speech from background noise. Using these spatial cues, adaptive binaural beamforming is applied to enhance the desired speech signal from the front while suppressing unwanted sounds from other directions. This directional beamforming effect is combined with the natural directional effect of the pinna, which is largely preserved by the microphone position in the ear canal.

The system continuously adapts to the acoustic environment, ensuring optimal speech focus while maintaining natural awareness of the surroundings. The synchronized processing allows the system to suppress unwanted background noise and improve speech clarity, even in complex acoustic situations with multiple competing speakers and high noise levels, thereby empowering wearers to effortlessly participate in conversations without the typical trade-off between audiological performance and hearing aid discretion.

Based on a range of indicators (e.g., continuous sound classification, and estimation of overall input level and noise floor level), the system monitors the surroundings and adapts to changes by smoothly transitioning between binaural beamforming and omnidirectional processing, depending on the listening needs in each situation. Thus, the directionality is only activated when relevant.

Unlike conventional single-microphone hearing aids, which only provide an omnidirectional response without directional enhancement, BOMD 2.0 enables Signia IX single-microphone hearing aids to offer a substantial improvement in the signal-to-noise ratio (SNR) for signals coming from the front, such as in a face-to-face conversation in background noise.

The two studies presented in this white paper assessed the directional benefit of BOMD 2.0 and the corresponding positive impact on speech understanding. For each study, we will explain the methods and present the results.

Technical study: Assessment of directionality

The Directivity Index (DI, American National Standards Institute, 2021) has long been the standard metric for quantifying the efficacy of directional microphones in hearing aids. The DI indicates how much diffuse background noise is attenuated relative to a sound with the same sound pressure level coming from the front. However, the DI measurement assumes static conditions and therefore does not work well with modern adaptive hearing aid microphones. In order to be able to meaningfully assess the efficacy of modern directional microphones, Aubreville & Petrausch (2015a) suggested an alternative method, which is based on the well-established Hagerman & Olofsson phase-inversion method (Hagerman & Olofsson, 2004) that allows separate analysis of speech and noise on the output side of the hearing aids. The outcome measure of the method is called the sequential Directivity Index (sDI). In this study, we have applied this method to assess the directional benefit of BOMD 2.0 technology when compared to competitor single-microphone hearing aids that do not offer directional technology.

Methods

Measurements were made on Signia Insio Charge&Go CIC IX (with and without activation of BOMD 2.0) and on CIC hearing aids from four main competitors (labeled Brand A-D), which at the time of the measurements were the most recent premium CIC hearing aids from the respective manufacturers. All the hearing aids were custom made to fit the ears of the KEMAR manikin and had no vent. The hearing aids were matched in gain across brands. They were initially programmed for a 40 dB HL flat hearing loss using the manufacturers' proprietary fitting rationales, but in order to allow the Hagerman & Olofsson phase-inversion method to provide the most reliable and accurate results, the gain was adjusted to be linear, and features like feedback cancellation and frequency compression that could disturb the phase of the output signal (and thereby violate the assumptions of the method) were turned off.

The hearing aids under test were positioned in the ears of the KEMAR (which included no internal parts that could disturb ear-to-ear communication between the left and right hearing aids). The KEMAR was placed in the middle of the loudspeaker setup (established in a low-reverberant room) shown in FIGURE 2, facing the loudspeaker at 0°, which was used to present the target speech. The distance between the KEMAR and the surrounding loudspeakers was 1 m.

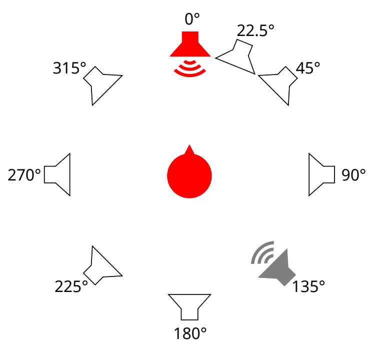

FIGURE 2 Loudspeaker setup used for measurement of the directional performance. The target signal was always played from the loudspeaker in front of the KEMAR, while the interferer signal was played from one loudspeaker at a time (135° is shown as an example in this figure). By turning the KEMAR so it faced the loudspeaker at 22.5°, it was possible to obtain a measurement resolution of 22.5°.

The target speech was the International Speech Test Signal (ISTS, Holube et al., 2010). While presenting the target speech from the front loudspeaker, an interfering speech signal (also the ISTS signal), which in this context acted as a disturbing noise signal, was presented from one of the loudspeakers in the setup, with one separate measurement done for each loudspeaker position (covering the full 360°). Both target and interferer were presented at a level of 75 dB SPL, measured at KEMAR's position.

In each measurement, the output of the left hearing aid was recorded and used for the analysis. Each recording was made twice, with and without phase inversion of the interfering signal. By application of the Hagerman & Olofsson phase-inversion method, the two recordings allowed estimation of the isolated target and interferer signals on the output side of the hearing aid. It was thereby possible to estimate the Interferer-to-Target Ratio (ITR), which indicates the level of the interferer signal relative to the target signal for a given interferer angle. By repeating the measurements for the different interferer angles, it was possible to measure the ITR for the full 360°. By turning the KEMAR towards the loudspeaker positioned at 22.5° and repeating the measurements without changing the positions of the loudspeakers, all interferer directions were shifted by 22.5°, and accordingly, it was possible to measure the ITR with a 22.5° resolution.

The sequential Directivity Index (sDI), which can be interpreted as the average SNR improvement for speech coming from the front while one interfering noise is presented from different directions across the full 360°, is calculated based on the ITR values in the same way as the traditional DI is calculated (see Aubreville & Petrausch (2015a) for calculation details). The frequency-dependent sDI was determined at 1/3 octave frequencies in the range 0.2-5 kHz. To provide one outcome value describing the overall directional performance, we applied a Speech Intelligibility Index (SII) weighting (American National Standards Institute, 2021) and then calculated the average across the entire frequency range. This outcome will be referred to as sSII-DI, and it can be interpreted as the SII-weighted average directional SNR benefit offered by the system being measured.

Results

The measured sDI values, indicating the directional benefit as a function of frequency, are plotted in FIGURE 3 for the two Signia settings (with and without activation of BOMD 2.0) and for each of the four competitor CICs.

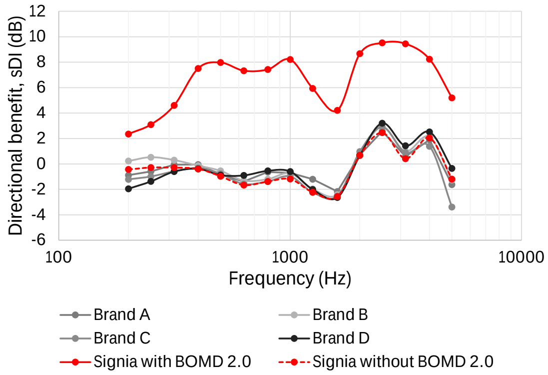

FIGURE 3 The sequential Directivity Index (sDI) for Signia Insio Charge&Go CIC IX (with and without activation of BOMD 2.0) and four main competitor CIC hearing aids (Brands A-D). The sDI was measured at 1/3 octave frequencies, and the measured values are connected by fitted curves.

The data in FIGURE 3 clearly shows that while the directional performance is very similar for the Signia CIC without BOMD 2.0 and all four competitors, which only offer omnidirectional processing, the directional performance of the Signia CIC with BOMD 2.0 activated was significantly enhanced compared to competitors. Activation of BOMD 2.0 had a substantial effect on sDI, which was 8-9 dB higher at some frequencies compared to the omnidirectional systems offered by the competitors.

The curves for the omnidirectional systems are almost identical, and their shapes are mainly determined by the acoustic effect of the pinna on the sound picked up by the microphone positioned in the ear canal. Thus, this well-known pinna effect is responsible for the increase in sDI in the 2-4 kHz frequency range, where positive sDI values (indicating an improvement of the SNR for a speech signal from the front) are observed.

The pinna effect also contributes to the shape of the sDI curve observed for the BOMD 2.0 measurement, but the binaural processing provides a significant additional directional effect.

FIGURE 4 shows the SII-weighted average sDI for the two Signia settings and each of the four competitor hearing aids. The results reflect the substantial differences observed in FIGURE 3. The sSII-DI for the Signia BOMD 2.0 setting was 7.3 dB, while all the values for the omnidirectional settings were slightly negative (in the range -0.48 dB to -0.04 dB).

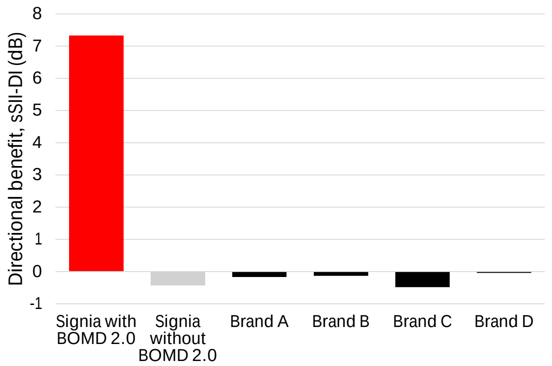

FIGURE 4 SII-weighted average of sDI (sSII-DI) for the two Signia settings and the four competitors.

Thus, FIGURE 3 shows that the BOMD 2.0 technology offers a directional SNR benefit of more than 7 dB when compared to the conventional single-microphone hearing aids, for which the directional performance is determined by the pinna effect – leading to almost identical performance across brands. Increasing the SNR by 7 dB corresponds to increasing the ratio between the intensity of speech and the intensity of noise by a factor of five.

Human performance study: Speech understanding in noise

To confirm that the technical benefits of BOMD 2.0 observed in the technical study translate into human performance benefits, a second study was conducted in the labs of the University of Northern Colorado, USA, with the aim of testing the effects of BOMD 2.0 on speech understanding in noise using a standardized speech-in-noise test.

Methods

The study included 17 participants. Their average age was 69 years (SD: 13 years, range: 25-80 years), and they included 10 females and 7 males. All participants had a sensorineural hearing loss, with the average audiogram shown in FIGURE 5.

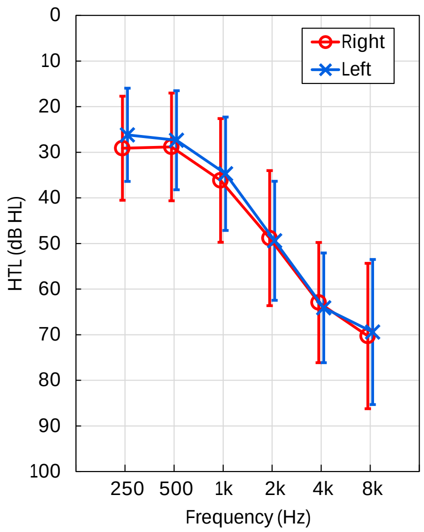

FIGURE 5 Mean right and left audiogram for the 17 participants. Error bars indicate ± one standard deviation.

The participants were fitted binaurally with Signia Silk Charge&Go IX hearing aids with BOMD 2.0 technology. Power sleeves were used for all fittings. The fitting rationale was NAL-NL2, and REM measurements were performed to verify that the target was matched. The hearing aids were programmed with two different test programs: 1) a program with BOMD 2.0 activated, and 2) a program with BOMD 2.0 deactivated, i.e., offering traditional omnidirectional processing (referred to as "OMNI"). The gain and all other feature settings in the two programs were identical.

To test the participants' ability to understand speech in noise with each of the two programs, a modified version of the American English Matrix test (Hörtech, 2019) – which is the American English version of the standardized German Oldenburger Satztest (OLSA; Wagener et al., 1999) – was conducted. The test was conducted in a sound-treated room using the loudspeaker setup shown in FIGURE 6. The participant was seated in the center of the setup, with a distance of 1.5 m to each of the surrounding loudspeakers.

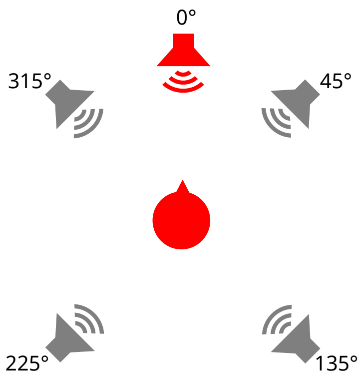

FIGURE 6 Loudspeaker setup for the Matrix speech-in-noise test. Target sentences were presented from a loudspeaker in front of the participant, while masking noise was presented from four other loudspeakers around the participant.

In the test, Matrix test sentences were presented from the loudspeaker in front of the participant (at 0° azimuth), while noise was presented from four other loudspeakers (at 45°, 135°, 225° and 315° azimuth). The task of the participant was to repeat each sentence, and the number of correctly repeated words was scored by a researcher. While the level of the background noise was fixed at 67 dBA, the level of the speech was changed adaptively after each sentence to find the SNR where 80% of the words could be repeated correctly. This outcome measurement will be referred to as the Speech Reception Threshold for 80% speech understanding (SRT80).

The background noise was created by presenting other Matrix test sentences from the four loudspeakers around the participant. These masker sentences were presented uncorrelated and with all gaps between sentences removed. Additional speech babble was presented at a level 15 dB below the masker sentences.

The test consisted of 30 sentences presented for each of the two hearing aid conditions, OMNI and BOMD 2.0. Prior to the actual test, two training runs with 20 sentences each were completed to familiarize the participant with the test. The order of the two hearing aid programs was counterbalanced across the participants.

Results

The mean SRT80 across the participants for the two test conditions, OMNI and BOMD 2.0, are shown in the bar graph in FIGURE 7.

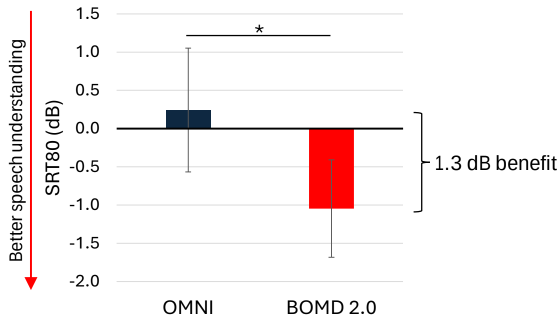

FIGURE 7 Mean SRT80 for the two test conditions, OMNI and BOMD. Error bars indicate the standard error of the mean. The asterisk indicates a statistically significant difference ($p < .05$).

The graph indicates a clear difference between the two programs. For OMNI, the mean SRT80 was 0.2 dB, while it was -1.1 dB for BOMD 2.0. Accordingly, since a lower SRT80 score indicates better performance, BOMD 2.0 provided a mean benefit of 1.3 dB. This difference was statistically significant according to a paired t-test ($t(16) = 2.47$, $p < .05$). Thus, as expected, the activation of BOMD 2.0 resulted in a significant improvement in speech understanding in the complex listening scenario included in the test.

Discussion

The technical study showed that BOMD 2.0 provided an improvement of the sSII-DI of more than 7 dB compared to the omnidirectional microphone systems provided by competitors (as well as by Signia CICs without activation of BOMD 2.0). This means that the overall SNR will be improved by more than 7 dB on average when a wearer listens to speech from a talker in front of them while interfering noise – such as distracting speech – arrives from another direction.

An SNR increase of 7 dB corresponds to increasing the acoustic intensity ratio between speech and noise by five times, and accordingly, a wearer of Signia hearing aids with BOMD 2.0 technology will experience five times more speech enhancement than provided by the omnidirectional systems currently implemented in competitor single-microphone hearing aids.

BOMD 2.0 also delivers notable improvement over the already-proven benefit of the original BOMD 1.0. This is demonstrated when the data from the present study are compared to previous data obtained with version 1.0. When Signia CIC hearing aids with the BOMD 1.0 technology were introduced, sDI measurements were done using methodology that is comparable to the study presented in this paper. At that time, Articulation Index (AI)-based weighting was applied when calculating the average sDI, rather than the SII-weighting applied in the present study. However, the two weightings are quite similar, and if the AI-weighting is applied to the new sDI data measured for BOMD 2.0, an sAI-DI value of 7.2 dB is obtained. This value is more than 2 dB higher than the sAI-DI value of 5.1 dB reported by Aubreville & Petrausch (2015b) for BOMD 1.0. This substantial difference indicates an even larger benefit offered by the BOMD 2.0 technology implemented on the IX platform compared to the original version.

Seen in isolation, the technical SNR improvement provided by BOMD 2.0 is likely to result in a clear improvement in the ability to understand speech in noisy backgrounds. However, there are factors other than SNR that contribute to speech understanding, and furthermore, real-world listening situations are rarely "perfect" with noise coming from one direction at the time. On the contrary, they are often quite complex with distracting noise coming from multiple directions. To confirm that the observed technical benefit of BOMD 2.0 results in improved speech understanding in a complex communication scenario, we conducted the human performance study at the University of Northern Colorado.

The study indeed showed a significant improvement in speech understanding when BOMD 2.0 was activated compared to omnidirectional processing. The magnitude of the observed SRT80 benefit was smaller than the magnitude of the observed technical sSII-DI benefit, but that was expected due to the complex test scenario where noise was presented simultaneously from multiple directions from the front and back hemispheres, as well as from the left and right hemispheres.

The observed speech understanding improvement of 1.3 dB is both statistically and clinically significant, and it may be the difference between being able to follow a conversation and having to give up in a real-world listening situation where a hearing aid wearer would struggle to understand speech using conventional omnidirectional processing.

While the two studies reported in this paper use different approaches to investigate the effect of the BOMD 2.0 technology, the results are aligned and together they show that BOMD 2.0 can deliver a substantial directional SNR benefit to the wearer, and that this SNR benefit translates into a significant speech understanding benefit in a challenging communication situation, like a conversation in noise.

For hearing care professionals, the ability to provide small single-microphone hearing aids with the directionality offered by Signia's BOMD 2.0 technology means they can offer a unique solution for hearing aid wearers who need support in challenging communication situations in noise but do not wish to compromise on the discretion provided by CIC hearing aids. In fact, it could be argued that the speech enhancement in noise delivered by BOMD 2.0 – which was demonstrated in these studies – adds to the discretion of the small hearing aids by drawing less attention to the hearing loss of the wearer.

Summary

Uniquely in the industry, Signia offers directional speech enhancement in noise in single-microphone hearing aids via Binaural OneMic Directionality (BOMD) 2.0 technology. It's enabled by the low-latency, wide-bandwidth binaural link (e2e 4.0) offered by the Signia Integrated Xperience platform. In this paper, we have presented results from two studies assessing BOMD 2.0.

In the first (technical) study, a directional SNR benefit of more than 7 dB was observed when BOMD 2.0 was compared to single-microphone systems offered by premium CIC hearing aids from four key competitors. This corresponds to five times more speech enhancement delivered by Signia CIC hearing aids with BOMD 2.0 compared to the competition.

In the second (human performance) study, a statistically significant SRT80 improvement of 1.3 dB, indicating a significant improvement in speech understanding, was observed when BOMD 2.0 was activated.

Together, the results from the two studies confirm the unique ability of the BOMD 2.0 technology to offer directionality in single-microphone hearing aids, providing a clear speech enhancement advantage to the wearer without having to compromise on discretion.

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