Phonak Field Study News.

Spheric Speech Clarity applies DNN processing to significantly improve speech understanding from any direction and reduce the listening effort.

Results of a study investigating speech in noise (SiN) benefits of Phonak Audéo Sphere™ Infinio found that with Spheric Speech Clarity (SSC), users are 2 times more likely to understand speech in noise compared to without it and up to 3 times more likely compared to two leading competitors.

Wright, A., Keller, M., Kuehnel, V., Latzel, M., Seitz-Paquette, K., August 2024

Key highlights

- SSC is Phonak's solution to understanding speech in noise, using a large-scale DNN to reduce noise from all-around the listener, with a measured 10dB SNR benefit.[1]
- SSC's processing is powered by the DEEPSONIC AI chip, which is, at time of launch, the fastest and most powerful chip in hearing aid technology.
- In tasks measuring speech understanding and listening effort, SSC performed significantly better than previous Phonak technology and two leading competitors.

Considerations for practice

- Discuss how Spheric Speech Clarity enables effective communication in dynamic listening situations by improving speech understanding from any direction.
- Counsel users on the lesser known side effects of hearing loss, like fatigue, and how an advanced noise reduction system like Spheric Speech Clarity can reduce listening effort so they have more energy at the end of the day.

Introduction

Speech understanding in complex and noisy environments is a common topic in hearing aid research. Often cited as one of the highest priorities for those with hearing loss, satisfaction for hearing in noise has remained low.[2,3] Hearing aid manufacturers have continuously invested in advancing technology to address this specific difficulty, resulting in innovation that is generally focused on two types of solutions– directional microphones and noise reduction algorithms.

Evidence of directional microphones improving signal-to-noise ratio (SNR) and, consequently, behavioral performance, is well documented,[4] however, directional microphones rely upon the speech of interest being inside of the directional beam of the microphone, and, ideally, with the noise located primarily outside of it. Directional microphone technology is highly effective, but there is an opportunity to innovate a solution that is more suitable for dynamic communication needs with off-axis speech and co-located noise.

Noise reduction is a broad term with implementations well beyond hearing aids. Arguably, consumer applications (e.g., Teams, Zoom) have exceeded the noise reduction capabilities of hearing aids through the use of deep neural networks (DNN), which require significant processing power, unique architecture and power efficiency in order to run. DNN noise reduction systems overcome the limitations of directional microphones by providing SNR improvements for speech from any direction.[5] Hearing aids have been slow to adopt large-scale DNN systems due to a number of factors, not least of which are the limited capabilities of current hearing aid processors.

Phonak Audéo Sphere Infinio features two processors working in parallel: the ERA chip to provide for traditional signal processing and other functions of the hearing aid, such as conventional noise reduction algorithms, and the DEEPSONIC chip to run Spheric Speech Clarity, a DNN-based noise reduction system. DEEPSONIC was developed specifically to apply DNN-based signal processing on a hearing aid to enhance speech and suppress noise, overcoming the hardware limitations that have, until now, prevented a large-scale DNN-based noise reduction system from being applied in a hearing aid.

Technical measures comparing the SNR benefit of Spheric Speech Clarity to previous Phonak technology and competitor devices were initially conducted. The combination of Spheric Speech Clarity and a fixed directional (FD) microphone setting delivered 10dB SNR benefit (with SSC at maximum strength) compared to an omni directional microphone setting without noise reduction applied. Additional technical measures using an unaided condition as the baseline, showed that Phonak Audéo Sphere Infinio delivered up to 3.7dB more SNR benefit compared to two leading competitor devices.

Based on these promising technical results, a clinical investigation with two arms was conducted at the Phonak Audiology Research Center (PARC) to examine the benefits of this unprecedented implementation of DNN-based signal processing. The study arm reported in the present paper evaluated the benefits for speech understanding in noise and listening effort. The second arm evaluated the performance of Phonak Audéo Sphere in daily life.[6]

Methodology

Participants

Twenty-seven experienced adult hearing aid users with moderate to moderately severe bilateral hearing loss aged 58 to 93 years (m = 75.1 ± 8) were recruited for this study. Otoscopy was conducted prior to testing, as well as cerumen management on an as-needed basis.

Hearing instruments

Three sets of receiver-in-canal (RIC) hearing instruments were fit according to manufacturer fitting software recommendations. However, there were three exceptions: (1) if frequency lowering or frequency compression defaulted on then it was turned off, (2) user controls on the hearing instruments were disabled, and (3) the acoustic coupling was set to a custom earpiece with a pressure vent. In order to reduce variability from physical fit, all participants had three duplicate pairs of custom earpieces with one pair affixed to each set of hearing instruments. Receiver power was determined per the manufacturer software. Feedback testing was run on ear for each set of hearing aids to ensure no instruments were unfairly disadvantaged due to poor physical fit. No fine-tuning was permitted since the study protocol sought to understand how each manufacturer's default signal processing, including gain prescription, would perform in complex listening tasks.

Comparisons

This study included two comparisons – an internal comparison that isolated the effect of SSC without interference from additional sound cleaning features and a competitive comparison that compared Audéo Sphere Infinio to the highest technology tier of two leading competitors' most recent models, as of March 2024.

The internal comparison was measured using manual programs called SSC on and SSC off. SSC on was achieved with a Spheric Speech in Loud Noise program with the microphone mode set to Real Ear Sound (RES) and Spheric Speech Clarity at its default setting. SSC off was achieved with a Speech in Noise program with the same microphone mode as SSC on (RES), but with all noise reduction features turned off (e.g. Dynamic Noise Cancellation and NoiseBlock). The gain models of the Spheric Speech in Loud Noise and Speech in Noise programs are the same, thus the only meaningful difference between these manual programs was that SSC on had SSC active while SSC off had no noise reduction.

The competitive comparison was measured using manufacturer default settings for Phonak's Spheric Speech in Loud Noise program and two leading competitor speech-in-noise manual programs. Please note that this Spheric Speech in Loud Noise program is different from the program used in the internal comparison with respect to the microphone setting. At default, Spheric Speech in Loud Noise uses an FD microphone.

The internal comparison between SSC on vs SSC off was used for both the speech understanding and the listening effort tasks. To avoid participant fatigue, the comparison with competitors was only used for the speech understanding task.

Speech understanding

Speech understanding in noise was measured using the speech corpus developed by Bolia et al. (2000),[7] which became known as the Coordinate Response Measure (CRM) stimuli.

Participants were seated in a speaker array with loudspeakers located at 60, 120, 180, 240, and 300 degrees with the touchscreen placed at 0 degrees. They were instructed to press "Start" on the touchscreen and listen for a sentence with the structure "Ready, Baron, go to [color] [number] now.". Participants then had to identify the color and number spoken in that sentence by selecting them from a closed set displayed on the touchscreen. Sentences were spoken by two female talkers, and the talkers were randomized throughout the test. After making their selection the participants received feedback indicating the correct response, and the next test sentence was initiated.

Broadband noise matched to the average speech spectrum of the talkers was presented from all loudspeakers for a fixed summated output level of 72 dB SPL. The speech sentences were randomized across only four of the five loudspeakers at 60, 120, 240, and 300 degrees (Fig.1). Speech output was 69 dB SPL, resulting in a -3 dB SNR.

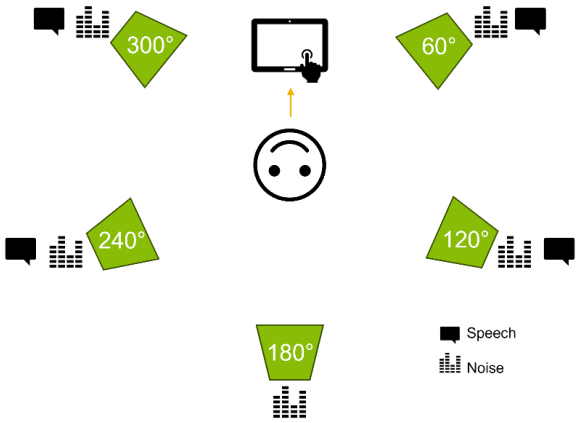

Figure 1. Schematic of the acoustic setup for the speech understanding task.

Listening effort

The Adaptive Categorical Listening Effort Scaling (ACALES) test is an adaptive method of measuring subjective listening effort.[8] Three short sentences (US female matrix test speech corpus) were presented sequentially in fixed speech shaped noise. Participants rated their subjective listening effort on a 13-point scale ranging from 'effortless' to 'extremely effortful'. After each rating, the volume of the speech was adapted. The algorithm of the ACALES is designed to capture the range in SNR that includes both the effortless and extremely effortful rating for an individual.

The same loudspeaker configuration was used in the listening task as in the speech understanding task; however, participants were turned 180 degrees so that a speaker was located at 0 degrees azimuth. The speaker at 0 degrees presented the speech while the other four loudspeakers presented the noise at a fixed summated output level of 72 dB SPL. The initial output level for the speech was 72 dB for a starting SNR of 0 dB (Fig. 2).

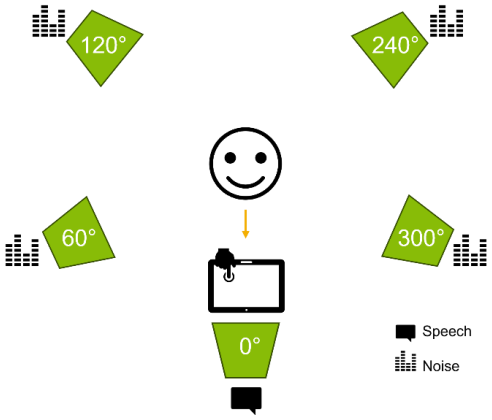

Figure 2. Schematic of the acoustic setup for the listening effort task.

Results

Speech understanding

Percent correct for each condition was calculated by taking the sum of correct responses from the four possible speech locations and dividing by the sum of the total number of responses. The percent correct results were then used to calculate the percentile change by subtracting the percent correct of the poorer performing condition from the percent correct of the better performing condition, dividing this difference by the percent correct of the poorer performing condition, and finally multiplying the result by 100 (Equation (1)).

$$\%\ change = \frac{\%\ \text{correct (better)} - \%\ \text{correct (poorer)}}{\%\ \text{correct (poorer)}} x\ 100 \quad (1)$$

Internal comparison

The internal comparison of SSC on vs. SSC off found a percentile change of 13.05% in favor of SSC on, showing that with Spheric Speech Clarity, average performance was 13.05% better with SSC compared to without it.

To contextualize the benefit of SSC beyond the study participants, participant responses were modelled using a generalized linear mixed-effects model with a logit link function. This model incorporated the hearing aid processing condition and sentence condition as fixed effects, while treating participants as random effects. The purpose of this model was to test whether the odds of providing a correct response significantly varied between different hearing aid processing conditions. The results can be interpreted as the ratio of the odds of providing a correct response under different hearing aid processing conditions. The model indicated that participants were two times more likely to give a correct response when using Spheric Speech Clarity than they were when not using it (odds ratio: 2.01, asymptotic 95% CI: [1.6, 2.52], p < 0.0001) (Fig. 5).

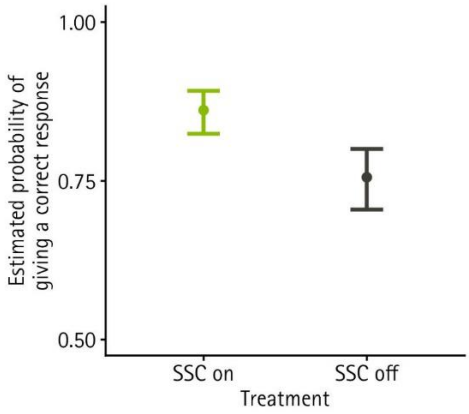

Figure 5. Estimated probability of giving a correct answer with and without Spheric Speech Clarity and an open microphone (e.g., Real Ear Sound; error bars indicate 95% confidence intervals).

Competitive comparison

The comparison of Spheric Speech in Loud Noise to competitor SiN programs revealed a percentile change of up to 36.74% in favor of Spheric Speech in Loud Noise. This indicates that with Spheric Speech Clarity implemented per the manufacturer defaults, the study participants were able to get up to 36.74% more answers correct with Audéo Sphere Infinio compared to two current competitors.

The odds ratios for the competitive comparison were also calculated via a generalized linear mixed-effects model following the same general structure as the internal comparison, but this time including hearing aid brand and sentence location as fixed effects. Results indicated that, with Spheric Speech Clarity, participants were more than two times more likely to give a correct response than with competitor 1 (odds ratio: 2.86, asymptotic 95% CI: [2.15, 3.79], p < 0.0001) and more than three times more likely to give a correct response than with competitor 2 (odds ratio: 3.41, asymptotic 95% CI: [2.54, 4.57], p < 0.0001) (Fig. 6).

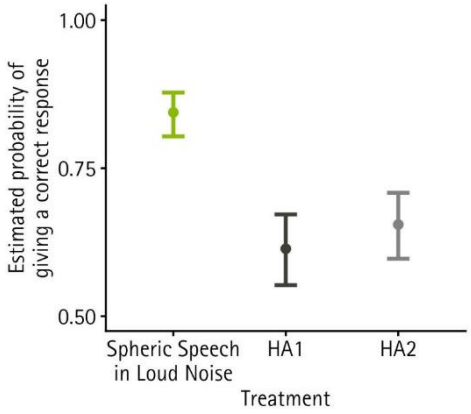

Figure 6. Estimated probability of giving a correct answer with Spheric Speech in Loud Noise and two competitor Speech in Noise programs (error bars indicate 95% confidence intervals).

Listening effort

Listening effort ratings were modelled using linear mixed effects model including hearing aid processing as fixed effect and participant as random effects. Model results indicated that with SSC on, participants could withstand 2.9 dB poorer SNR without a corresponding increase in subjective listening effort compared to SSC off (mean difference: -2.86 dB, 98% CI: [-3.32, -2.39], p < 0.0001) (Fig. 5). This means that noise can become 2.9 dB louder before a user reports an increase in their subjective listening effort.

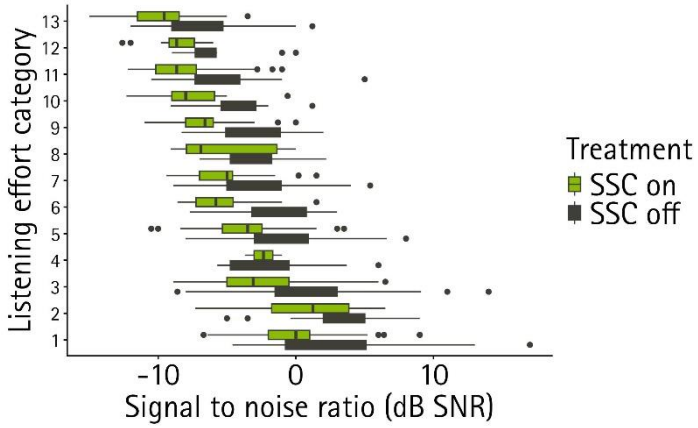

Figure 7. Horizontal box plots showing the range in SNR for each rating on the listening effort scale with and without Spheric Speech Clarity.

Conclusion

This study provides evidence that the technical measures[1] of Phonak Audéo Sphere Infinio translates into perceptual speech understanding and listening effort benefit. More specifically, Phonak Audéo Sphere Infinio outperformed competitors for speech understanding in noise when the speech was off-axis and the noise was co-located. These two benefits align with commonly reported needs by those with hearing loss,[2,3] making Phonak Audéo Sphere Infinio the premier choice for end-users seeking the most effective solution for communicating in noise.

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Acknowledgements

The authors would like to acknowledge D.N. and A.B. for their enthusiasm and contributions to this study.

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