PHONAK
life is on

Phonak Field Study News.

Neuroimaging evidence of reduced listening effort with Spheric Speech in Loud Noise

This paper summarizes a peer-reviewed study which is among the first to report on the use of the functional Near-Infrared Spectroscopy (fNIRS) neuroimaging technique to measure changes in prefrontal cortical oxygenation with different hearing aid features (Vaisberg et al., 2025). The Spheric Speech in Loud Noise program reduced listening effort and improved listening accuracy. It was linked to reduced activity in the brain areas related to cognitive effort, lessening cognitive demands for listening in noise compared to use of the Calm Situation program.

Vaisberg, J. & Greenham, P., May, 2026

Introduction

Listening in noise is one of the most challenging tasks for hearing impaired individuals. As the signal of interest gets harder to hear, the cognitive demands and effort required to listen increase (Rovetti et al., 2022). This can ultimately result in listening fatigue and withdrawal from the interaction (Alhanbali et al., 2017). Over the past two decades, hearing aid manufacturers have relied on improvements in directional microphones and noise reduction algorithms to improve speech recognition performance and to reduce listening effort.

Listening effort is a complex multidimensional process requiring the allocation of cognitive resources and purposeful effort to attend to the signal of interest (Pichora-Fuller et al., 2016, Alhanbali et al., 2019). It can be measured using self-assessment scales or inferred from behavioural or physiological responses such as pupillometry, dual-task paradigm, EEG or functional brain imaging (Pichora-Fuller et al., 2016). Functional near infrared spectroscopy (fNIRS) is a non-invasive and portable neuroimaging technique that measures blood flow and oxygenation levels using near infrared light (Shatzer at al., 2023). It measures reduced oxygenation in a specific brain area, which is indicative of reduced cognitive activity and can be used infer changes in listening effort (Rovetti et al., 2019). Previous studies have demonstrated that fNIRS can be used to measure oxygenation changes in the prefrontal cortex which correspond to differences in task demands in older adults who use hearing aids (Rovetti et al., 2019 and 2022, Vaisberg et al., 2024). Easier listening conditions (better SNR and use of hearing aids) resulted in lower prefrontal cortex oxygenation and were associated with improved listening accuracy and reduced subjective listening effort (Rovetti et al., 2019 and 2022, Vaisberg et al., 2024).

The Phonak Audéo Sphere hearing aid incorporates Spheric Speech Clarity (SSC), a deep neural network (DNN) that uses artificial intelligence to extract and enhance speech from a noisy background. It uses a complex filter approach, trained on millions of samples, to accurately separate speech from background noise more effectively than traditional methods [used in other hearing aids]. Noise reduction with Spheric Speech Clarity has been shown to improve understanding of speech in diffuse noise by 13% compared to standard quiet-listening settings in people with moderate-to-severe hearing loss and by 20-30% in coincident noise from the front compared to quiet-listening or directional microphone programs in those with severe-to-profound hearing loss (Saoji et al., 2024, Keller et al., 2024, Wright et al., 2024). Latzel, M et al. (2025) showed that Spheric Speech Clarity 2.0 was able to boost speech understanding by 50% compared to StereoZoom (SZ). In addition, subjective listening effort, measured via the Adaptive Categorical Listening Effort Scaling (ACALES; Krueger et al., 2017) method, was found to be lower with SSC than with the Speech in Loud Noise (SiLN) program with SZ.

The aim of this study was to use fNIRS to compare outcomes between:

1. Phonak's Spheric Speech in Loud Noise program, with Spheric Speech Clarity, directional microphones and slow-acting compression
2. Phonak's Calm Situation (quiet listening) program with omnidirectional microphones, speech enhancement and fast-acting compression

The authors of the present study are unaware of any prior work using fNIRS to investigate cortical differences between hearing aid features. Measures of speech perception and subjective listening effort were also included.

Methodology

Subjects

Twenty-six English-speaking participants (mean age ± SD = 69.2 ± 7.1 years; 14 males, 12 females) were recruited from Phonak's Audiology Research Centre Canada research database. All participants were experienced bilateral hearing aid users (mean experience ± SD = 9.5 ± 8.5 years) and presented with a symmetrical mild sloping to moderately-severe sensorineural hearing loss.

Design

A one-factor (two-level) repeated-measures within-subjects design was used. Each participant completed the experiment in a single two-hour session scheduled during standard daytime hours. Participants were informed that different hearing aid programs would be used during testing but were not told how the programs were expected to influence listening performance, nor were they informed when each program would be presented.

Primary outcome measure

Cerebral oxygen exchange was measured via fNIRS, which captures the combined changes in oxygenated (HbO) and deoxygenated (HbR) blood, reflecting the degree of activation as oxygenated blood enters and deoxygenated blood exits a region (HbDiff = HbO - HbR). HbDiff is a sensitive indicator of cerebral activation and has previously been used to assess cognitive effort, including listening effort (Rovetti et al., 2022; Vaisberg et al., 2024).

fNIRS device

An OctaMon continuous-wave fNIRS device (Artinis Medical Systems, Netherlands) was used to make the measurements with six active optodes and two short-separation optodes, consisting of eight LED diode emitters (wavelengths: 760 and 850 nm) and two photodiode detectors, sampled at 10 Hz. The light emitters and detectors were spaced approximately 3.5 cm apart, allowing penetration of about 1.75 cm into the cortex. The device was positioned over the participant's prefrontal cortex. Figure 1 (top) illustrates the fNIRS device as worn by a participant, while Fig. 1 (bottom) shows the optode montage overlaid on a 20-10 coordinate system.

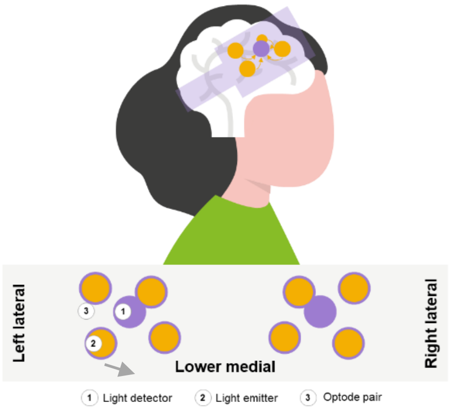

Figure 1. Schematic of fNIRS device used in this study. Eight light emitters (yellow circles) and two light detectors (magenta circles) placed over the prefrontal cortex, for a total six measurement optodes and two short-separation optodes.

Speech Reception Threshold Measurement

Individualized speech reception thresholds (SRT-50) were obtained so that participants would perform comparably in the main auditory task despite differences in thresholds or other characteristics. Target speech was presented from 0° azimuth with multitalker babble from 180° azimuth, and the noise level was fixed at 70 dB(A). Each SRT-50 was measured by participants repeating 20 sentence-final words from low-context Revised Speech Perception in Noise (R-SPIN sentences), with correct and incorrect responses lowering and raising the speech level, respectively, in subsequent sentences. Each run consisted of a single list, and the SRT-50 was calculated as the average over two lists. The average SNR-50 was –0.6 dB (SD = 3.9) across participants.

fNIRS auditory stimuli

Sentences for the main study task were taken from a single R-SPIN list not used in the speech reception threshold measurement. The signal-to-noise ratio was set at the participant's SRT-50 + 2 dB, where previous research has shown that listening effort peaks (Rennies et al., 2018). There were five testing blocks and each block contained a total of eight sentence sequences. Six test sequences contained three or more low-context sentences, and two "decoy" sequences contained one or two high-context sentences. Participants had one practice block using the standard-listening program. The four test blocks were randomly allocated to either the standard- or Spheric Speech in Loud Noise -listening conditions for a total of 16 sequences per condition. Each sequence was separated by a 30-second silent baseline recording period where participants were asked to minimize movement and mind-wandering. Participants were instructed to repeat the last word of the last sentence in the sequence and then provide the number corresponding to their average listening effort rating for all the sentences in the sequence. Listening effort was measured on a 7-point Likert scale where 1=no effort, 2=very little effort, 3=little effort, 4=moderate effort, 5=considerable effort, 6=much effort and 7=extreme effort (Johnson et al., 2015).

Statistical Analysis

Subjective listening effort ratings and listening accuracy scores were averaged per participant for each program. Listening accuracy scores were transformed to rationalized arcsin units (RAU) to reduce clustering of scores near ceiling performance. To assess the effect of the hearing aid program on subjective listening effort and on listening accuracy, paired sample t-tests were conducted. A standardized effect size was calculated for each test using Cohen's d.

Blood oxygenation (HbDiff) was analysed using multilevel modelling (MLM), with HbDiff specified as the dependent variable. The primary predictor was hearing aid program (Spheric Speech in Loud Noise vs Calm Situation)), alongside an interaction term between program and prefrontal subregion (left lateral, lower medial, right lateral).

Results

Speech perception and subjective listening effort

Mean listening accuracy significantly improved (p=0.01) and subjective listening effort significantly reduced (p<0.001) with use of the Spheric Speech in Loud Noise program (table 1). Average subjective listening effort reduced from moderate effort to little effort. Listening accuracy was 14% higher for the Spheric Speech in Loud Noise program compared to the Calm Situation program (figure 2).

Measure	Mean (SD)	t (df)	p	95% CI	Cohen's d (effect size)
Standard effort	4.02 (0.89)	10.05 (25)	<.001	[0.75, 1.13]	1.97 (large)
DNN effort	3.08 (0.96)				
Standard accuracy	62.30 (19.40)	−2.64 (25)	.01	[−24.03, −2.98]	0.52 (medium)
DNN accuracy	75.80 (15.20)				

Table 1. Mean scores and statistical significance for measures of listening effort and listening accuracy.

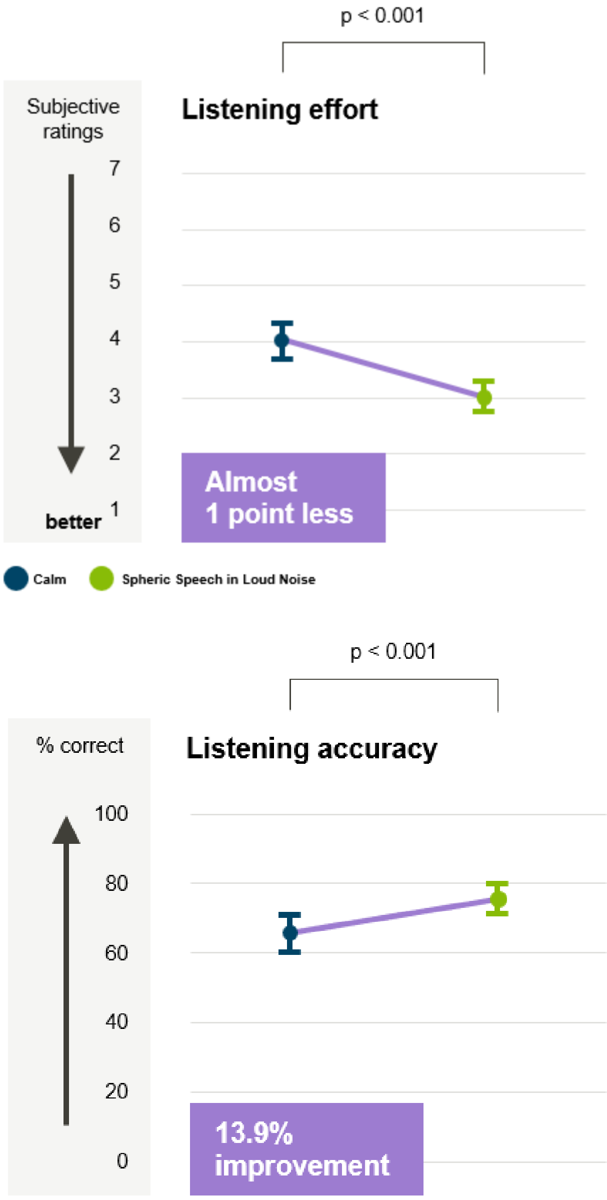

Figure. 2. Mean listening effort (top) and listening accuracy (bottom). Error bars represent the standard error of the mean. *p <.05. ***p <.001. Reproduced from Vaisberg et al., 2025, under CC BY 4.0.

Cerebral oxygen exchange

The hearing aid program had a significant effect on blood oxygenation in the left lateral prefrontal cortex while controlling for handedness. On average, blood oxygenation levels decreased by −18.97 units during the DNN-listening program, compared to the standard-listening program (b = −18.97, 95% CI [−30.86, −7.08], p =.0018). There was no effect of the hearing aid program on blood oxygenation levels in the right lateral (p =.62) or the lower medial (p =.93) prefrontal cortex (figure 3).

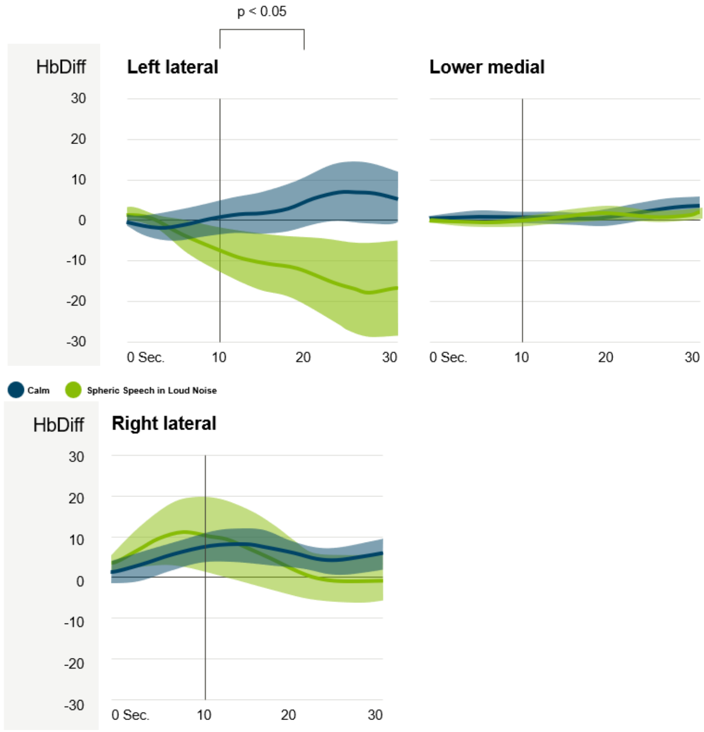

Figure. 3. HbDiff (HbO – HbR) normalized time series data for the left lateral subregion averaged across participants. Shaded regions represent one standard error of the mean. The blue shaded area is Phonak's Calm Situation standard start-up program. The green shaded area is Phonak's Spheric Speech in Loud Noise program with DNN-based noise management. Reproduced from Vaisberg et al., 2025, under CC BY 4.0.

When focusing on correct trials only, cortical oxygenation mirrored changes in subjective listening effort. Blood oxygenation increased by 7.89 units for every 1-unit increase on listening effort ratings (b = 7.89, p =.035). Incorrect trials were excluded as these might have included lapses in attention or disengagement due to task difficulty.

Future research

The specific contribution of Spheric Speech Clarity could not be disentangled from that of directional processing. Therefore, future work should look to isolate the individual contributions of each of these factors. The benefit of the DNN-listening program is related to the SNR at which it is used. Speech perception was measured at a level that was optimal for fNIRS. Future measurement at varying SNRs may be more sensitive to improvements in speech perception due to the use of the DNN listening program.

Conclusion

This study supports fNIRS as an effective and useful tool for measuring the impact of hearing aid features in experienced older adult hearing aid users. The area of the brain associated with effortful listening consumed less energy during speech in noise when participants listened with

Spheric Speech in Loud Noise as compared to a Calm Situation program. Reduced activation in the brain regions associated with effortful listening during difficult tasks suggests lower cognitive demands when using Spheric Speech in Loud Noise. This aligned with improved speech understanding with listening accuracy increasing by 14% and subjective listening effort decreasing from moderate to little effort.

The combination of beamforming and DNN-based noise management technology used in the Spheric Speech in Loud Noise program exclusively available on Audeo Sphere Infinio devices, reduced listening effort, improved listening accuracy and may have lessened cognitive demands compared to other hearing aid programs. The benefits of these types of advanced signal processing may not always be captured by conventional behavioural metrics, particularly under favourable acoustic conditions where intelligibility is already near ceiling. In such contexts, physiological insights - such as those afforded by fNIRS - offer a critical means of revealing underlying differences in listening effort that may be imperceptible behaviourally.

References

Alhanbali, S., Dawes, P., Lloyd, S., & Munro, K. J. (2017). Self-Reported Listening-Related Effort and Fatigue in Hearing-Impaired Adults. *Ear and hearing*, *38* (1), e39–e48. https://doi.org/10.1097/AUD.0000000000000361

Alhanbali, S., Dawes, P., Millman, R. E., & Munro, K. J. (2019). Measures of Listening Effort Are Multidimensional. *Ear and hearing*, *40* (5), 1084–1097. https://doi.org/10.1097/AUD.0000000000000697

Johnson, J., Xu, J., Cox, R., & Pendergraft, P. (2015). A Comparison of Two Methods for Measuring Listening Effort As Part of an Audiologic Test Battery. *American journal of audiology*, *24* (3), 419–431. https://doi.org/10.1044/2015_AJA-14-0058

Krueger, M., Schulte, M., Brand, T., & Holube, I. (2017). Development of an adaptive scaling method for subjective listening effort. *The Journal of the Acoustical Society of America*, 141(6), 4680-4693.

Latzel, M., Heeren, J., Lesimple, C., Gökalan, M., Puhlemann, L., Haf, C. (2025). Spheric Speech Clarity improves speech understanding and reduces both listening effort and fatigue. *Phonak Field Study News,* retrieved from https://www.phonak.com/evidence

Pichora-Fuller et al. (2016). Hearing Impairment and Cognitive Energy: The Framework for Understanding Effortful Listening (FUEL). *Ear and Hearing 37 Suppl 1*, 5S–27S. https://doi.org/10.1097/AUD.0000000000000312

Rennies, J., Pusch, A., Schepker, H., & Doclo, S. (2018). Evaluation of a near-end listening enhancement algorithm by combined speech intelligibility and listening effort measurements. *The Journal of the Acoustical Society of America*, *144* (4), EL315. https://doi.org/10.1121/1.5064956

Rovetti, J., Goy, H., Pichora-Fuller, M. K., & Russo, F. A. (2019). Functional Near-Infrared Spectroscopy as a Measure of Listening Effort in Older Adults Who Use Hearing Aids. *Trends in hearing*, *23*, 2331216519886722. https://doi.org/10.1177/2331216519886722

Rovetti, J., Goy, H., Zara, M., & Russo, F. A. (2022). Reduced Semantic Context and Signal-to-Noise Ratio Increase Listening Effort As Measured Using Functional Near-Infrared Spectroscopy. *Ear and hearing*, *43*(3), 836–848. https://doi.org/10.1097/AUD.0000000000001137

Saoji, A. A., Sheikh, B. A., Bertsch, N. J., Goulson, K. R., Graham, M. K., McDonald, E. A., Bross, A. E., Vaisberg, J. M., Kühnel, V., Voss, S. C., Qian, J., Hogan, C. H., & DeJong, M. D. (2024). How Does Deep Neural Network-Based Noise Reduction in Hearing Aids Impact Cochlear Implant Candidacy?. *Audiology research*, *14* (6), 1114–1125. https://doi.org/10.3390/audiolres14060092

Seitz-Paquette, K., Keller, M., Miller A., Wright, A., Kuehnel, V., Latzel, M., Raufer S., Hobi S. (2024). Leveraging deep neural networks in hearing aids. *Hearing. Review. 31*, 8–15 https://hearingreview.com/hearing-products/hearing-aids/speech-in-noise/leveraging-deep-neural-networks-in-hearing-aids

Shatzer, H. E., & Russo, F. A. (2023). Brightening the Study of Listening Effort with Functional Near-Infrared Spectroscopy: A Scoping Review. *Seminars in hearing*, *44* (2), 188–210. https://doi.org/10.1055/s-0043-1766105

Vaisberg, J. M., Dang, C., Jiang, Y., Qian, J., & Russo, F. A. (2025). Brain benefits of deep learning-based noise management in experienced hearing aid users using functional near infrared spectroscopy. *Scientific reports*, *15* (1), 41815. https://doi.org/10.1038/s41598-025-25801-y

Vaisberg, J. M., Gilmore, S., Qian, J., & Russo, F. A. (2024). The Benefit of Hearing Aids as Measured by Listening Accuracy, Subjective Listening Effort, and Functional Near Infrared Spectroscopy. *Trends in hearing*, *28*,

23312165241273346.
https://doi.org/10.1177/23312165241273346

Wright, A., Kuehnel, V., Keller, M., Seitz-Paquette, K., Latzel, M. (2024). Spheric Speech Clarity applies DNN signal processing to significantly improve speech understanding from any direction and reduce the listening effort. *Phonak Field Study News* retrieved from https://www.phonak.com/evidence

Authors and investigators

Lead Investigator

Jonathan Vaisberg, PhD, is a Research Scientist at Sonova, where he leads clinical research including concept exploration, product validation and post-market studies. His doctoral work, focused on optimizing hearing aid signal processing for music-listening, sparked his interest to develop innovative hearing solutions with high-impact outcomes. A licensed audiologist, Jonathan completed concurrent clinical and research training in Audiology and hearing science at Western University's National Centre for Audiology (London, Canada).

Author

Paula Greenham is an Audiological Scientist with expertise in cochlear implants. In 2010, she founded her own company, providing research planning, management, and scientific writing support in audiology. She has contributed to numerous scientific publications and collaborated with researchers, clinicians, surgeons, and hearing technology companies to strengthen evidence for hearing interventions, helping to inform clinical practice and public policy through rigorous research and scientific communication.

Phonak Field Study News.

One-page summary

Neuroimaging evidence of reduced listening effort with Spheric Speech in Loud Noise

The Spheric Speech in Loud Noise program reduced listening effort and improved listening accuracy. It was linked to reduced activity in the brain areas related to cognitive effort, lessening cognitive demands. Vaisberg et al. (2025) report one of the first uses of functional Near-Infrared Spectroscopy (fNIRS) to assess cortical differences in hearing aid features.

Vaisberg, J. & Greenham, P., May, 2026

Key highlights

- This study shows how fNIRS was used to measure the impact of different hearing aid features on cortical activation in experienced older adult hearing aid users.
- When using Spheric Speech Clarity subjects reported that it was little effort to hear in noise and listening accuracy was improved by 14 %. Cognitive demands were reduced.

Considerations for practice

- Counsel users on how an advanced noise reduction system like Spheric Speech in Loud Noise can not only improve listening accuracy but also reduce listening effort and cognitive load, so they have more spare mental capacity for other tasks and more energy at the end of the day.

Vaisberg, J. M., Dang, C., Jiang, Y., Qian, J., & Russo, F. A. (2025). Brain benefits of deep learning-based noise management in experienced hearing aid users using functional near infrared spectroscopy. *Scientific reports*, *15* (1), 41815. https://doi.org/10.1038/s41598-025-25801-y