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Speech Enhancer reduces subjective listening effort of speech by up to 45%

This study, conducted at the Hörzentrum Oldenburg found that with Speech Enhancer activated, the subjective listening effort for distant/soft speech is reduced by 39%. When speech comes from an adjacent room, the subjective listening effort is reduced by 45%.

Habicht, J. & Schuepbach-Wolf, M. June, 2024

Key highlights

- ACALES was used to assess subjective listening effort while Electroencephalographic (EEG) measurements were used to detect neurophysiological differences when Speech Enhancer was activated.
- With Speech Enhancer activated, the subjective listening effort for distant/soft speech is reduced by 39%.
- When speech comes from an adjacent room, the subjective listening effort is reduced by 45%.
- EEG analyses did not reveal statistical differences between two talker locations (distant speech in same room or adjacent room) nor between Speech Enhancer turned on or off. In other words, on the neurophysiological level no clear effect of the Speech Enhancer technology could be detected.

Considerations for practice

- People with hearing loss report the need for increased mental/listening effort to compensate for difficulties arising from their hearing impairment.
- Speech Enhancer is an adaptive algorithm designed to enhance the peaks of a soft speech signal in quiet situations.
- Speech Enhancer was first introduced in 2020 with Paradise premium devices (performance level 90) and was set as default for users selected as 'experienced users' and 'long-term users' in Phonak Target. In the Infinio platform, Speech Enhancer is now on by default, also for new users. It can be set anywhere between 0 (off) and 20 (strong).
- A separate study found that the use of Speech Enhancer reduced the accumulation of fatigue by 21% during a time-compressed auditory day (Latzel et al., 2024).

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Introduction

Numerous studies have found that people with hearing loss report the need for increased attention, concentration and mental/listening effort to compensate for difficulties arising from their hearing impairment (Hétu et al., 1988; Kramer et al., 2006).

Speech Enhancer is an adaptive algorithm in Phonak hearing aids which was first introduced in 2020. At the time of writing, it is available in Paradise, Lumity and Infinio platform hearing aids. It is designed to enhance the peaks of a speech signal in quiet situations (Pittmann et al., 2023). Up to 10 dB additional gain will be applied in the following circumstances:

- Speech between 30-50 dB input level is detected; and
- Signal-to-Noise Ratio (SNR) is at least +10dB

The main benefit of giving hearing aid users access to Speech Enhancer is that it aims to improve understanding of speech in quiet. Hearing speech in quiet is the biggest predictor of hearing aid benefit (Dillon, 2018). Speech Enhancer is activated when hearing aid users are in the Calm situation program of AutoSense OS. We know from our Datalake Fitting Data that hearing aid users are in Calm situation at least 68% of the time*. It could be hypothesized that if Speech Enhancer improves speech intelligibility of quiet or distant speech, that this would require less listening effort.

Speech Enhancer has already been intensely and successfully investigated in other studies. Appleton-Huber, 2020, found that participants with moderate-severe hearing loss showed less listening effort when listening to distant speech, both in a paired comparison and a listening effort scaling paradigm. Latzel, 2023, found that participants with moderate-severe hearing loss showed less listening effort with Speech Enhancer ON in comparison to Speech Enhancer OFF, when listening to distant speech using the Adaptive Categorical Listening Effort Scaling (ACALES) procedure.

EEG and listening effort

Listening effort on a neurophysiological level has already been successfully investigated in a previous study (Winneke A. H., 2020). In a first experiment, 20 experienced subjects (severe hearing loss) showed less subjective listening effort, when listening with narrow directional microphone (DM, StereoZoom) than wide DM (RealEarSound) using the ACALES, as well as reduced electroencephalographic (EEG) alpha power for the narrow directional microphone (DM). During the EEG experiment, participants had to listen to sentences in cafeteria noise and were asked to rate the experienced listening effort (ACALES combined with EEG).

Further studies have also provided evidence that a reduction in alpha power (measured using EEG) is associated with a reduction in cognitive (listening/working memory) effort in noisy environments (Jensen, 2020; Klimesch, 2007; Obleser, 2012; Wisniewski, 2017; Winneke A. D., 2018; Winneke A. S., 2018; Nawaz, 2023).

Therefore, as well as further evaluating the subjective benefit of Speech Enhancer on listening effort, the current investigation was also designed to evaluate the effect of Speech Enhancer on a neurophysiological level using EEG measurements. This was done while the subject performed a series of different listening tasks with the use of soft voice levels simulating situations with distant speech when the talker is in the same room or speech coming from an adjacent room (see figure 2).

Methodology

A total of 27 experienced (minimum 6 months of use) hearing aid users took part in the study. 13 were men, 14 were women. The age range was 30 to 81 years (mean 69.6 years, SD 11.6 years). The hearing loss of the participants was in the mild-severe range. The mean hearing threshold is shown in figure 1.

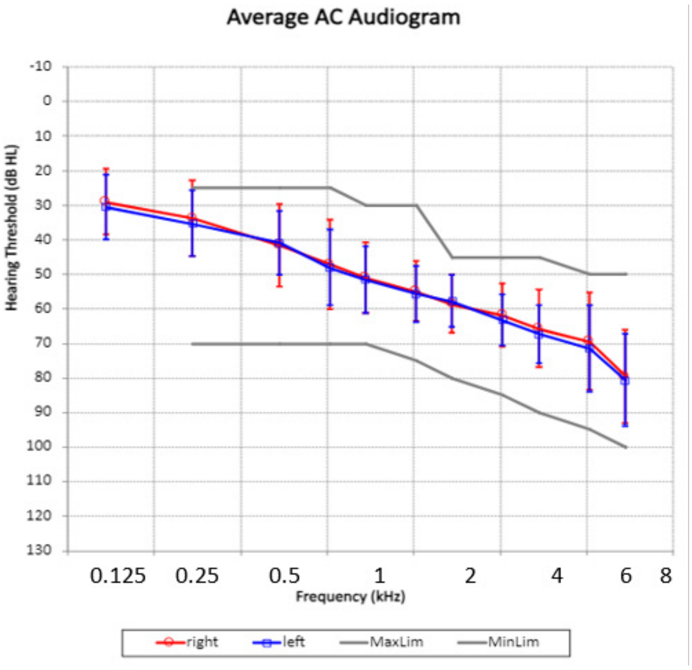

Figure 1. Mean hearing aid threshold of participants. The gray lines mark the inclusion area according to the inclusion criteria for the participants.

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*Phonak Datalake Fitting Data extrapolated on 14th May 2024 for Phonak Lumity users with usage time, in the US.

Participants were fit with Phonak Audéo™ Lumity (Audéo™ L90-R) rechargeable hearing aids. They were fit with two manual programs:
Calm Situation: Speech Enhancer OFF (0) (SE OFF)
Calm situation: Speech Enhancer ON (20) (maximum strength) (SE ON)

Speech material was presented in quiet from one loudspeaker at a distance of 4m (i.e. distant speech) in a reverberant environment (right part of figure 2) and from an adjacent room with the door left ajar (left part of figure 2). Both scenes (rooms) were acoustically simulated using a 16 Loudspeaker ambisonics setup controlled by TASCAR (G. Grimm, 2016; Grimm, Luberadzka, & Hohmann, 2019). The speech level was calibrated at a distance of 4m (A-weighted).

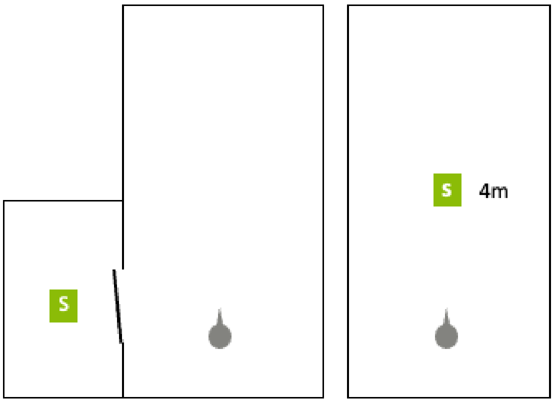

Figure 2. Setup for talker from adjacent room (left) and distant talker (right). Green square with 'S' represents the speaker/talker.

The Oldenburg Sentence Test (OLSA) (Wagener, 1999) was performed during the screening to define optimum speech level (SRT50% in dB) for the following measurements.

ACALES/ Listening Effort Task

The speech material of the ACALES was based on the German OLSA sentence matrix test. Participants were asked to rate their perceived listening effort on a scale via touch screen. The scale ranges from 1 (no effort) to 14 (not heard) based on the ACALES (Krüger, 2017). These values (effort scaling units - ESCU) constituted the subjective behavioral data regarding the personal experience of listening effort. The original ACALES scale was modified in this study by renaming the final level ("noise only") to "not heard" since the presented signals were speech in quiet without background noise. To ensure a good working level, the result of the OLSA in quiet was used (SRT50% for the level at 4m plus 3, 6.5 and 10 dB). In this study, every condition consisted of 10 blocks of 3 OLSA sentences (triplet). After each triplet participants were asked to rate their experienced listening effort.

EEG

A continuous EEG was recorded using a 24-channel wireless Smarting EEG system (mBrainTrain, Belgrade, Serbia) while participants were performing the listening effort task. The brain activity was recorded from 24 electrode sites mounted into a custom-made elastic EEG cap (EasyCap, Herrsching, Germany) and arranged according to the International 10–20 system (Jasper, 1958). Lab Streaming Layer (Kothe, 2014) and Smarting Streamer (mBrainTrain, Belgrade, Serbia) software are used to record EEG data. The EEG was recorded at a sampling rate of 500 Hz, with a low-pass filter of 250 Hz.

Results

ACALES/ Listening Effort Task

To analyze subjective listening effort ratings a 2 x 2 x 3 repeated measures ANOVA was conducted with the factors Speech Enhancer (ON vs. OFF), location (distance vs. adjacent room) and SNR (+3 dB, +6.5 dB, +10 dB). Figure 3 shows the results of the ACALES task. The results revealed a main effect of SNR (F = 142.65; p < .001) suggesting that an increase in volume reduces the experienced listening effort (3 dB > 6.5 dB > 10 dB). Furthermore, a main effect of Speech Enhancer showed that the subjective listening effort was significantly lower when the Speech Enhancer algorithm was activated (F = 123.12; p < .001). Figure 4 visualizes that the reduction in listening effort associated with the activation of the Speech Enhancer was 39% when the speech source was a distance of 4m and 45% when the speech source was in the adjacent room. However, the results did not indicate a significant main effect of location nor were there any interaction effects between the factors.

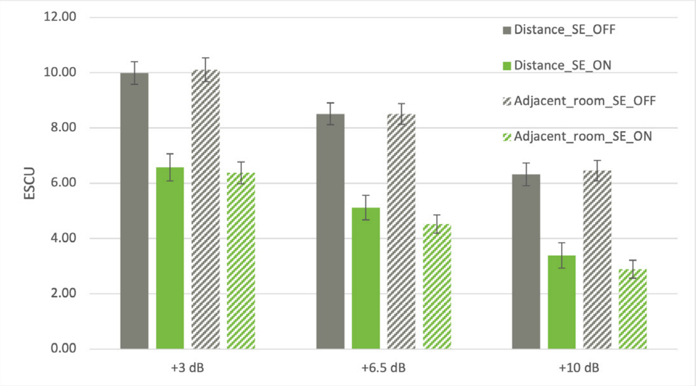

Figure 3. Results of the ACALES experiment showing mean listening effort scores (ESCU) for all the conditions (error bars reflect standard error).

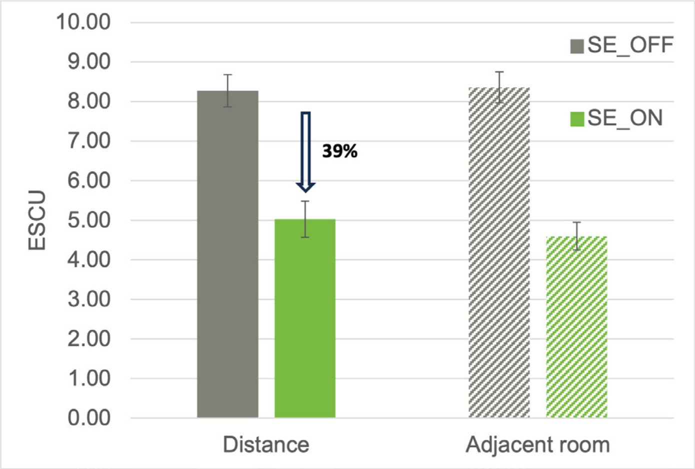

Figure 4. Results of the ACALES experiment showing the main effect of Speech Enhancer on mean listening effort scores (ESCU) (error bars reflect standard error).

EEG data

To investigate the neurophysiological markers during the listening effort experiment (ACALES), the analyses focused on the activity in the alpha EEG frequency band (7 to 13 Hz). Average Power Spectral Density (PSD) values of Alpha were extracted for each channel, condition and participant. Visual inspection of the topographical distribution revealed the strongest alpha activity at frontocentral electrode sites. This is in line with a previous study investigating the effect of directional microphone technology on listening effort (Winneke et al., 2020). For the statistical analyses, average PSD values for the frontocentral electrode sites Afz, F3, F4, Fz, Cz in the alpha frequency band of 7 to 13 Hz were computed.

To analyze EEG data of the ACALES experiment a 2 x 2 x 3 repeated measures ANOVA was conducted with the factors Speech Enhancer ON vs. OFF, location (distance vs. adjacent room) and SNR (+3 dB, +6.5 dB, +10 dB). Figure 5 and 6 show the results of the EEG data analysis of the ACALES task. The analysis revealed no significant effect of Speech Enhancer ($F = 1.24$; $p = 0.28$), of location ($F = 1.08$; $p = 0.31$) nor of SNR ($F = 1.64$; $p = 0.20$).

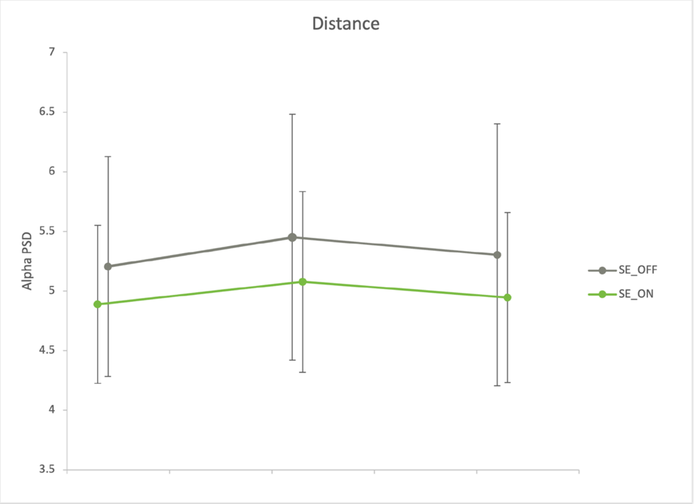

Figure 5. ACALES: Mean Alpha PSD values plus standard error bars of the Alpha frequency band (7–13 Hz) at frontocentral electrode sites for the condition: Location (Distance).

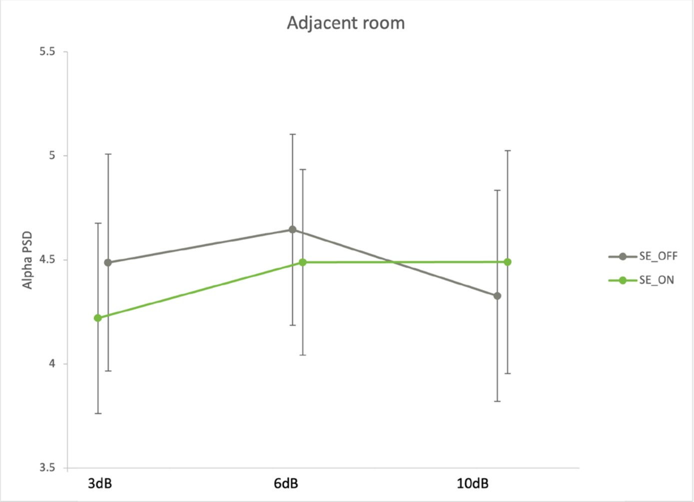

Figure 6. ACALES: Mean Alpha PSD values plus standard error bars of the Alpha frequency band (7–13 Hz) at frontocentral electrode sites for the condition: Location (Adjacent room).

Conclusion

The results of the listening effort experiment (ACALES) showed an increase in subjective ratings of listening effort with decrease in speech intensity levels as well as a clear benefit (i.e., lower subjective listening effort rating scores) when Speech Enhancer was turned on, for both locations (distance of 4m and adjacent room). This is in line with the previous study in which a narrow directional microphone was linked to lower listening effort ratings compared to a wider directional microphone (Winneke et al., 2020). Furthermore, the benefit of the Speech Enhancer technology was comparable for both location settings (speech from a distant talker in the same room as well as speech from a talker in an adjacent room).

EEG analyses did not reveal statistical differences between the two locations nor between Speech Enhancer turned on or off. In other words, on the neurophysiological level no clear effect of the Speech Enhancer technology could be detected. This could be due to a relatively large variation among participants particularly for the condition where the Speech Enhancer was turned off (see Figure 5 and 6). Also, in previous research the role of EEG-alpha in the context of listening effort has been linked to suppression of irrelevant information such as noise. Given that the current experiment was conducted in quiet there was little irrelevant information to be suppressed which might be a further explanation as to why the effect in the alpha frequency band was not as pronounced as in studies using speech in noise paradigms (Winneke et al., 2020).

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Authors and investigators

Internal investigators

Julia Habicht joined as Audiological Researcher Sonova Research & Development department in Switzerland in 2017. After training as a hearing aid acoustician in Lübeck in 2007, she studied Hearing Technology and Audiology at the University of Oldenburg, where she also completed her PhD in Neurosensory Science and Systems in 2018.

Martina Schuepbach-Wolf is an Audiological Researcher working at Sonova since 2011 in the Research & Development department in Switzerland. She is from Germany and worked as a hearing care professional for 5 years in Berlin. At the Luebeck University of Applied Sciences she studied hearing acoustics until 2011. Professionally, she enjoys working on new technology and studying the potential benefits and risks.

External investigators

Matthias Vormann has been working at Hörzentrum Oldenburg gGmbH in the field of audiology and projects since 2005. He works in clinical studies on scientific issues in industry studies and publicly funded projects as project manager and investigator. He received his Ph.D. from University of Oldenburg in 2011.

Axel Winneke received his M.Sc. in Biological Psychology from Maastricht University in 2004 and obtained his Ph.D in Experimental Psychology from Concordia University, Montreal, in 2009. His research deals with neurophysiological measurement of cognition and perception. He is currently a senior researcher at the Branch Hearing, Speech and Audio Technology of the Fraunhofer Institute for Digital Media Technology in Oldenburg, working on applied research projects in the area of Neuroergonomics with a specific interest in the topic of listening effort.

Müge Kaya has been working as a medical-technical assistant at the Hörzentrum Oldenburg since 2000, focusing on audiological hearing system evaluation, special audiological diagnostics, cross-project organization and subject acquisition.