Phonak Field Study News.

Speech Enhancer reduces listening effort and fatigue

This study conducted at the Hörzentrum Oldenburg found that the use of Speech Enhancer reduced subjective listening effort by 29% when listening to soft or distant speech. Listening with Speech Enhancer also reduced the accumulation of fatigue by 21% during a time-compressed auditory day.

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Key highlights

- Speech Enhancer leads to a significantly lower increase in subjective fatigue over the 2.5 hour test period. The fatigue effect was reduced by 21% (SE ON vs. SE OFF).
- Speech Enhancer was shown to significantly reduce listening effort. At a distance of 2 meters the subjective listening effort was calculated to have been reduced by 34% (SE ON versus OFF). When averaged over 2, 4 and 8 meters, the subjective listening effort reduction was calculated to be 29% (SE ON vs. OFF).
- The use of Speech Enhancer was also shown to significantly improve speech intelligibility in addition to memory and comprehension.

Considerations for practice

- Mental fatigue is a typical symptom reported by people with hearing loss (Hetu et al., 1988; Holman et al., 2019).
- 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 only for users selected as 'experienced 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 Speech Enhancer reduced listening effort by 45% when speech came from an adjacent room (Habicht et al., 2024).

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). Winneke et al. (2020) investigated the influence of different microphone modes on listening effort and found lower ratings of listening effort when using StereoZoom (binaural beamformer) versus real ear sound (omnidirectional, with directionality only in the higher frequencies) in lower signal-to-noise (SNR) situations. Effort consumes resources, and the cognitive system is thought to have finite resources available at any given time (Edwards, 2007). It's an opportunity cost, where resources used in one area (e.g., to support speech reading and top-down processing to complete information missed due to hearing loss) are unavailable elsewhere. This has been corroborated by McCoy et al. (2005), who found that older participants with hearing loss performed more poorly on a memory task (word recall) than a similar age group with normal hearing and concluded that this was caused by increased cognitive load. Intuitively, sustained listening effort over time may lead to 'mental' fatigue, defined as a decrease in cognitive performance due to sustained mental effort (DeLuca, 2005). Support for this comes from anecdotal and self-reports of stress and fatigue secondary to the communication difficulties arising from hearing loss (Hornsby, 2013; Hétu et al., 1988). Hornsby (2013) investigated listening effort and fatigue in 16 participants with sloping mild-to-severe hearing loss. He found significantly better recall of memorized words and faster reaction times in the aided versus unaided condition, implying the need to invest less listening effort when wearing amplification. Interestingly, whilst word recognition and memory recall remained relatively stable over repeated sessions in unaided and aided conditions, reaction times systematically increased when participants were not wearing their hearing aids, suggesting hearing aid use reduced mental fatigue.

Crowhen et al., 2022 and Blümer et al., (submitted) were able to demonstrate that sustained speech processing leads to increased mental fatigue. However, through the provision of hearing aids the amount of concentration needed and mental fatigue is reduced. Further, a visual concentration test (d2-R, Brickenkamp, 1962) revealed that mental processing speed was faster while wearing hearing aids relative to the unaided condition. This suggests that wearing hearing aids can reduce fatigue related to hearing loss and thereby improves overall well-being through enabling more efficient communication.

Speech Enhancer is an adaptive algorithm in Phonak hearing aids (Lumity platform and beyond) which 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
- SNR is at least +10 dB

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 and would lead to less mental fatigue.

The current study aimed to investigate whether activating the Speech Enhancer feature does lead to reduced listening effort and in turn reduced mental fatigue. Secondary objectives were to investigate whether Speech Enhancer improves speech intelligibility as well as memory and comprehension.

Methodology

22 experienced hearing aid users took part in this clinical investigation. Their median age was 76 years (min. = 55 max. = 83). 10 were female, 12 were male. Hearing thresholds were measured using pure-tone audiometry (see figure 1). The mean pure-tone average (PTA) was 58.5 dB HL (SD = 5.5 dB HL).

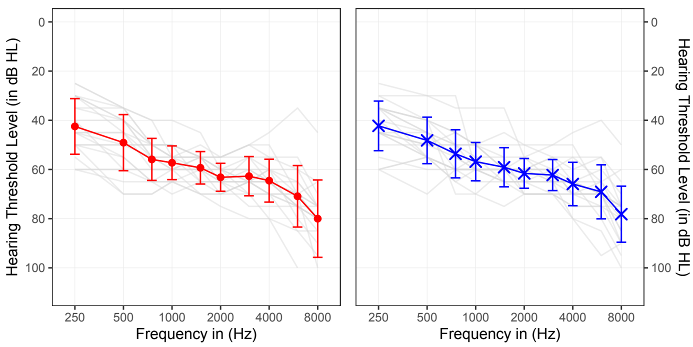

Figure 1. Mean hearing thresholds with one standard deviation for the right (red) and left (blue) ears. Individual audiograms are shown in grey.

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

Participants were fit with Audéo L90-R hearing aids (M or P receiver, according to hearing loss) using SlimTips without vents. They were fit on the Adaptive Phonak Digital (APD 2.0) fitting formula with frequency compression, adaptive features and AutoSense OS deactivated. They were fit with two manual programs:

Calm Situation: Speech Enhancer OFF (0)
Calm situation: Speech Enhancer ON (20) (maximum strength)
Real Ear Aided Response (REAR) measurements were obtained at 50, 65 and 80 dB SPL.

Fatigue
The general methodological approach of this study was the time-compressed-auditory day (TCAD; Blümer et al., submitted), which is a sequence of lab tests that concentrate listening challenges that occur during an exemplary day to a 2.5 hour test session. It aims for a simulation of fatigue with a high degree of ecological validity, while having controlled test conditions in a free-field-lab setup. To address situations where the Speech Enhancer is active, all tests were performed at low speech levels and without background noise. Within the TCAD, subjects rated their sensation of fatigue on a 10-point scale at the beginning of each test session followed by listening effort and fatigue after each listening test.
The subjective rating method was selected for the primary objective, because it allows for tracking the individual state of fatigue, whereas each of the included tests only allows for a single data point. The rating was performed eleven times for each of the conditions SE OFF and SE ON.

Subjective listening effort
As a part of the TCAD, participants performed a modified ACALES test (Krüger et al., 2017), where they rated the subjective listening effort for OLSA sentences as a function of the sound source distance. Therefore, sentences were convolved with room-impulse responses (1st order ambisonics) that were measured in a moderately reverberant room (T60 = 0.8 s) at distances of 2m, 4m, and 8m. They were presented via a horizontal loudspeaker setup with 16 loudspeakers. Presentation levels were 8 dB higher than individual Speech-Recognition Thresholds (SRT). Subjects rated listening effort on a scale from 1 (no effort) to 13 (extremely strenuous). This test was included as a reference, as it was already part of a previous study.

ACALES was performed two times for each of the conditions SE OFF and SE ON.

Speech intelligibility
The Concurrent OLSA test (CC-OLSA) is a speech recognition test with three turn-taking talkers presenting sentences of the Oldenburg sentences test (OLSA, Wagener et al, 1999a-c) at fixed signal-to-noise ratios (Heeren et al., 2022). In this study, speech was presented without background noise at levels of 5 dB above individual SRTs. CC-OLSA is also part of the TCAD. CC-OLSA measures speech recognition as a percentage of correct repetitions of target words and was performed two times for each of the conditions SE OFF and SE ON.

Memory and comprehension
In the Memory and Comprehension Test (Mirkovic et al. 2016), the participants listened to the German fairy tale "Zwerg Nase", which was presented 2 dB below individual SRTs. Afterwards, they filled in a questionnaire regarding the content of the fairy tale. Like the other tests, this test was included as a part of the TCAD. The Memory and Comprehension Test was performed two times for each of the conditions SE OFF and SE ON.

Results

Fatigue
Subjective fatigue ratings were repeatedly collected during the entire TCAD. The cumulative fatigue is the average of all these fatigue ratings. The change in fatigue between the start of the TCAD and the end of the TCAD was measured for the two conditions SE ON and SE OFF. Cumulative fatigue results are shown in figure 2. Using the cumulative value ensures that single test effects do not affect the overall perceived fatigue.

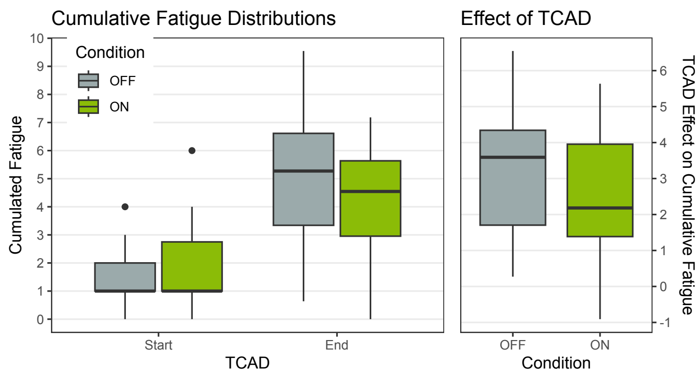

Figure 2. Distribution of the raw fatigue score (medians and interquartile ranges) for the start and the end of the TCAD on the left for SE ON (green) and SE OFF (grey). The within-subject effect of the TCAD is shown on the right.

The mean effect of TCAD on fatigue with SE OFF was 3.3 (SD = 1.1) and with SE ON 2.6 (SD = 1.1). TCAD effect on accumulated fatigue was significantly lower with SE ON vs. SE OFF (Median difference = -0.4), $p = 0.028$, $r = 0.406$. Speech Enhancer was therefore found to reduce the fatigue effect by 21% when carrying out the TCAD depending on its parameters.

Subjective listening effort

Listening effort scores from the ACALES test are shown in Figure 3. The ACALES was measured for 3 increasing talker distances: at 2m, 4m, and 8m twice during the TCAD. The distribution of the results combines the results for each repetition. Higher scores indicate increasing listening effort.

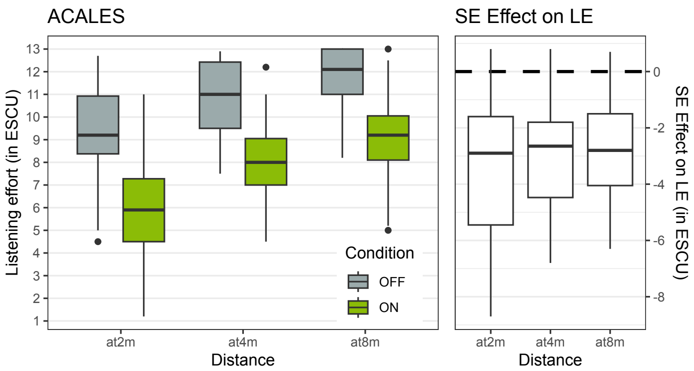

Figure 3. Distribution of the ACALES scores (medians and interquartile ranges) for increasing talker distances (from 2m to 8m) on the left for SE ON (green) and SE OFF (grey). The within-subject effect of the SE is shown on the right.

Speech Enhancer was shown to significantly reduce listening effort (mean effect = -3.1 ESCU, $p < 0.001$). At a distance of 2 meters, the listening effort was calculated to have been reduced by 34% (SE ON versus OFF). When averaged over 2, 4 and 8 meters, the reduction in listening effort was calculated to be 29% (SE ON versus OFF).

The effect of distance was significant ($p < 0.001$), suggesting that listening effort increases with talker distance: +1.8 ESCU from 2m to 4m and +0.9 from 4m to 8m. The effect of test repetition ($p = 0.08$) and its interaction with the test condition ($p = 0.95$) were not significant.

Speech intelligibility

Speech recognition scores from the CC-OLSA are shown in figure 4. The CC-OLSA test was repeated twice during the TCAD. Percent scores combine the talker-gender identification and the correct identification of the target word. Higher scores indicate better results.

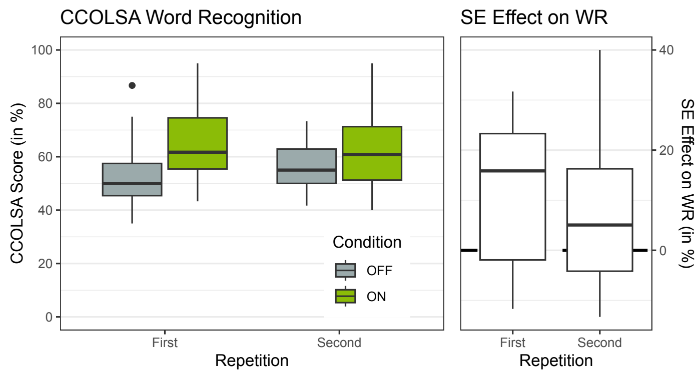

Figure 4. Distribution of the CCOLSA speech recognition scores (medians and interquartile ranges) for both repetitions during the TCAD on the left for SE ON (green) and SE OFF (grey). The within-subject effect of the SE is shown on the right.

Speech Enhancer was shown to significantly improve speech intelligibility by 9.2 % ($p < 0.001$). The effect of test repetition ($p = 0.35$) and its interaction with the test condition ($p = 0.16$) were not significant.

Memory and comprehension

Distribution of the number of correct responses from the Memory-and-comprehension test are shown in Figure 5. The test was repeated twice during the TCAD and higher scores stand for better results.

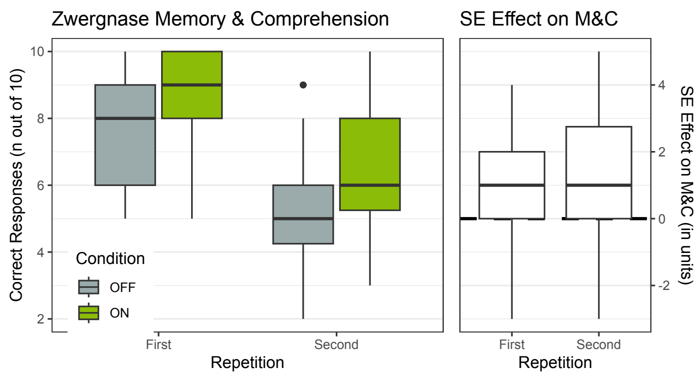

Figure 5. Distribution of the correct responses from the memory & comprehension test (medians and interquartile ranges) for both repetitions during the TCAD on the left for SE ON (green) and SE OFF (grey). The within-subject effect of the SE is shown on the right.

Speech Enhancer was shown to significantly improve memory and comprehension by 1 unit ($p < 0.001$). There was also a significant effect of test repetition ($p < 0.001$), i.e. scores at the end of the TCAD were 2 units lower than at the beginning. There was no significant interaction between the test condition and the repetition ($p = 0.54$).

Conclusion

Studies by Hornsby (2013) and Blümer (submitted) suggested that hearing aid use reduces mental fatigue. This study is the very first reporting significant differences in fatigue when activating a single hearing aid feature.

Speech Enhancer in Lumity devices has been shown to significantly reduce the fatigue effect when users listen to soft speech over a longer period of time. This is highly relevant given the evidence which shows that mental fatigue is a common symptom reported by people with hearing loss (Hetu et al., 1988; Holman et al., 2019). Furthermore, Speech Enhancer has been shown to lead to improved speech intelligibility, less listening effort and higher memory-and comprehension performance. This demonstrates the multiple benefits of activating Speech Enhancer for hearing aid users.

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Authors and investigators

Internal investigators

Dr. Matthias Latzel studied electrical engineering in Bochum and Vienna in 1995. After completing his Ph.D. in 2001, he carried out his Postdoc from 2002 to 2004 in the Department of Audiology at Giessen University. He was the head of the Audiology department at Phonak Germany from 2011. From 2012 to 2022 he has been working as the Clinical Research Manager for Phonak AG, Switzerland. Since 2022 he is senior expert clinical studies for Sonova AG.

Christophe Lesimple studied music in Stuttgart, audiology in Lyon, and statistics in Paris and Bern. He is working as a research audiologist and contributes to various aspects of development including concepts, supporting clinical trials, and analyzing data. Besides his activities with Sonova, he teaches audio analytics for machine learning at the University of Applied Science in Bern, hearing aid verification at the Akademie Hören Schweiz, and volunteers for a hearing-impaired association.

External investigators

Jan Heeren studied Physics at the University of Oldenburg, Germany, and graduated in the Medical Physics group in 2014. From 2012, he worked on several projects in the field of hearing aid evaluation and virtual acoustics at the university and at Hörzentrum Oldenburg gGmbH, where he is employed as a project manager since 2016. Apart from his scientific activities, he has conducted more than 500 events as a freelancing audio engineer since 2008.

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Author

Jennifer Appleton-Huber received her M.Sc. in Audiology from the University of Manchester in 2004. Until 2013, she worked as an Audiological Scientist mainly in the UK and Switzerland, where she worked with adults and pediatrics, in the areas of hearing aids and cochlear implants. Her current role is Scientific Audiologist within Global Audiology at Phonak Headquarters.