Phonak Field Study News.

Phonak hearing instrument technology reduces both listening effort and fatigue

Fatigue is a common report for those with hearing loss. This study illustrated that Phonak hearing aids and associated technology can reduce overall concentration required and fatigue as well as improve performance on cognitive tasks relative to unaided conditions.

Crowhen, DJ., Gordon, CMD., Latzel, M. December 2022

Key highlights

- Participants reported lower overall concentration required and fatigue across the "time-compressed acoustic day" (Heeren et al., 2022) when wearing hearing aids versus without them.
- When using hearing aids and the TV connector, participants had both significantly faster reaction times, suggesting decreased cognitive load for speech recognition, and improved accuracy compared to the unaided condition.
- The d2-R results showed that at the end of the time-compressed acoustic day participants had significantly faster processing speed when they had been wearing hearing aids compared to the unaided condition.

Considerations for practice

- The impacts of hearing loss extend beyond reduced speech understanding and include the need for people with hearing loss to invest additional attention and effort to piece together what is being said, which, overtime, can also lead to fatigue.
- Results of the current study suggest that hearing aids used in combination with wireless accessories such as a TV streamer for far-field listening situations can reduce overall listening effort and fatigue, enabling preservation of cognitive resources for other activities.
- Measures of effort and fatigue could, in future, provide a useful method to help validate the wider benefits of amplification beyond enhancing speech intelligibility.

Introduction

It is well known that people with hearing loss have difficulty hearing and understanding speech, especially in background noise (Dillon, 2012). Perhaps less appreciated is the additional effort often required by people with hearing loss to fill in any gaps using techniques like top-down processing and speech reading. Indeed, 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). Listening effort, defined as 'the mental exertion required to attend to, and to understand an auditory message' (McGarrigle et al., 2014), can be measured in several ways. This includes self-report (Alhanbali et al., 2017), behaviorally through reaction time (Houben et al., 2013) by assessing performance on dual tasks (Gosselin & Gagné, 2010; Sarampalis et al., 2009) or physiologically, using either pupillometry (e.g., Zekveld et al., 2010), skin conductance (Mackersie et al., 2015) or electroencephalography (EEG) (Obleser & Kotz, 2011). Studies incorporating these measures have demonstrated that hearing aids may reduce listening effort. For example, Noble & Gatehouse (2006) found that hearing aid use significantly reduced subjective ratings of concentration, listening effort and distractibility. Bentler et al. (2008) investigated the impact of digital noise reduction on effort and found that activating this feature significantly improved ratings of ease of listening. More recently, Winneke et al. (2018) investigated the influence of different microphone modes on listening effort using subjective ratings and objective EEG (alpha band activity, where more activity is considered representative of higher levels of effort). They found both lower ratings of listening effort and lower levels of alpha band activity 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). They found that older participants with hearing loss performed more poorly on a word recall task 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 (Hornby, 2013; Hétu et al., 1988). Hornby (2013) investigated listening effort and fatigue in 16 participants with sloping mild-to-severe hearing loss using a serial, dual-task paradigm assessing word recognition, word recall and reaction time (RTs) in both unaided and aided (omni and directional) conditions. He found significantly better recall and faster RTs in the aided versus unaided condition, implying the need to invest less listening effort when wearing amplification. Interestingly, whilst word recognition and recall remained relatively stable over repeated sessions in unaided and aided conditions, RTs systematically increased when participants were not wearing their hearing aids, suggesting hearing aid use reduced mental fatigue. Such findings of reduced listening effort and fatigue through amelioration of hearing loss with amplification form part of a more comprehensive framework highlighting the importance of good hearing for overall wellbeing (Vercammen et al., 2020). The current study's goal was to explore further the impact of amplification on hearing effort and fatigue.

Methodology

Twenty experienced hearing aid users (10 female/10 male) with a mild to moderate sensorineural hearing loss (mean 4 Frequency Pure Tone Audiogram = 32.4 ± 5.3dB HL) and normal cognitive function (assessed by Demtect, Kalbe et al., 2004) were recruited to the study. Participants were fitted with Phonak Audéo M90-312 hearing aids programmed at default settings for their hearing loss (including activation of adaptive parameters and frequency shifting as relevant for their hearing profile). Participants underwent two "Time-Compressed Acoustic Days (TCAD)" (Heeren et al., 2022) (one unaided, one aided – randomized order across subjects) during which they undertook various listening and attention tasks over 3 hours (see Table 1 for additional information on the order and type of acoustic tasks.) Performance on each task was measured, and in between each task, participants were also asked to make a subjective rating of the level of concentration/effort (0=no concentration, 10=High level of concentration) and mental fatigue (0=No fatigue, 10=Very fatigued) required.

Task	Test Description	Type	Task Measure
D2-R	Circle d and II, 57 symbols 20sec / row (Brickenkamp, 1962)	Visual	Speed (ms) Number correct
OLSBY I OLSBY II OLSBY III	Dual task* 1. Memory of recognized words of OLSA (Wagener et. Al, 1999 2. Reaction time when screen highlighted red *According to Hornsby (2013)	Visual and auditory	Correct word count and reaction time
OLERT I OLERT II	Presentation of a novel for two scenarios I: Target (0°), Distractor diffuse II: Target: TV (0°), Distractor: radio at 270° Press right button for trigger word "Harry" and left button for trigger word "Er"	Auditory	Reaction time (RT) and response accuracy
Attended Speaker I Attended Speaker II	Presentation of fairy-tale through a virtual door. Distractor radio scene	Auditory	Selective attention comprehension test
CCOLSA (Heeren at al, 2021)	Turn-taking paradigm for three talkers presenting OLSA sentences Target: switching talkers Noise: Diffuse pub background 1. Detect call sign ("Kerstin") 2. Understand and repeat last word	Auditory	Correct word count and correct call sign detection

Table 1. Summary of tests used in the time-compressed acoustic day

Results

The dose-dependent effect of each listening task at a given time point and over the day is illustrated in Fig 1. The overall concentration is high in all measurements and in both test conditions throughout the time-compressed listening day. In the unaided condition, required concentration increased significantly more than in the aided condition (general linear model (GLM), $p < 0.01$). The most significant difference was after the second administration of the OLERT test.

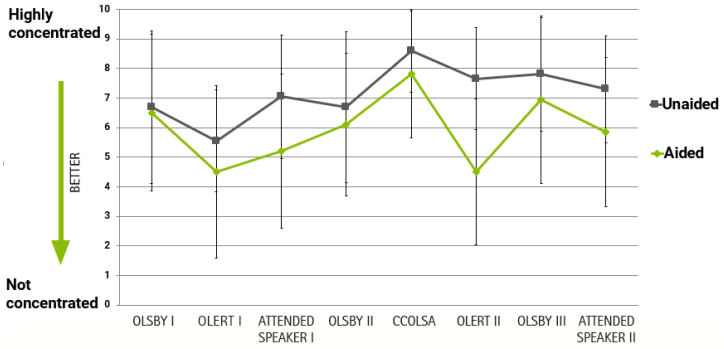

Figure 1. Average subjective concentration ratings for each attention task in aided and unaided condition. Concentration was measured using a scale (0 = No concentration required, 10 = high level of concentration required).

Objective results (RT and accuracy) from the OLERT test are illustrated in Fig 2 and show that in both the radio (OLERT I, hearing aids alone) and TV (OLERT II, Hearing aids + TV connector) scenarios, both RT and accuracy improved, with a significant difference for the TV condition ($p<0.05$) where the signal was transmitted via a TV connector. These performance benefits are accompanied by lower ratings of required effort on the OLERT in the aided versus unaided condition (see Fig 1 – concentration ratings for OLERT test).

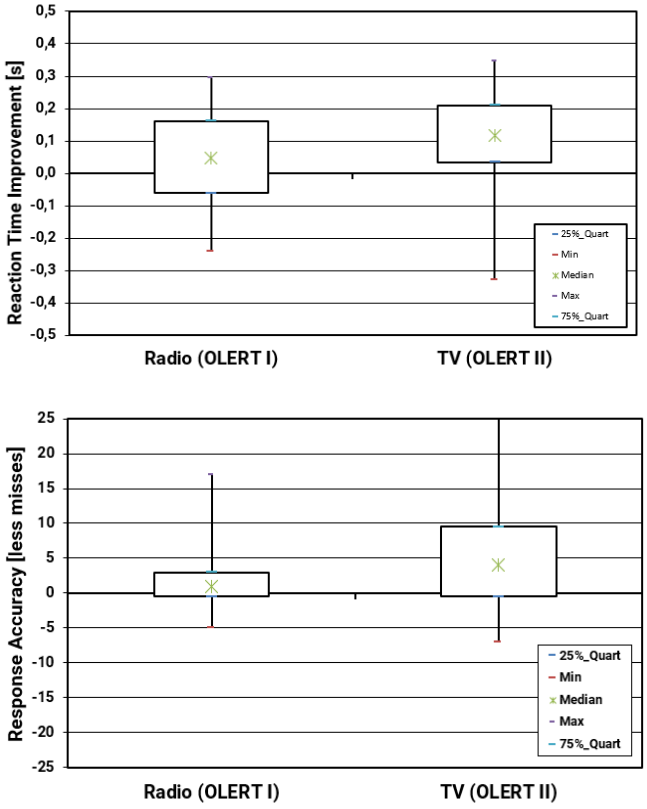

Figure 2. OLERT test results showing the impact of hearing aids alone (radio scene (OLERT I)) and hearing aids + TV connector (TV scene (OLERT II)) on (A) - Reaction time and (B) –Response accuracy. A paired t-tests showed significantly faster reaction times (reflecting less effort) and increased accuracy with hearing aids + TV connector versus the unaided condition ($P<.05$).

Figure 3 illustrates subjective fatigue ratings, which is described as the 'consequence' of integrated listening effort over the course of the day. Similar to required concentration (Fig 1), fatigue increases in both aided and unaided conditions throughout the time-compressed acoustic day, but to a greater degree in the unaided condition. To further explore the impact of amplification on fatigue, average fatigue ratings for two sets of tests (set#1: OLSBY I, OLERT I and Attended Speaker I; set#2: OLSBY II, OLERT II and Attended Speaker II) which were administered twice during the time-compressed acoustic day were compared. Figure 4 illustrates average fatigue rating over the course of the time-compressed listening day. While fatigue is evident in unaided and aided conditions, hearing aid use significantly lessened the amount of fatigue development from beginning to end of the day (GLM, $p < 0.05$). Further, rated fatigue was significantly greater in the unaided versus aided condition at the end of the time compressed acoustic day (GLM, $p<0.005$).

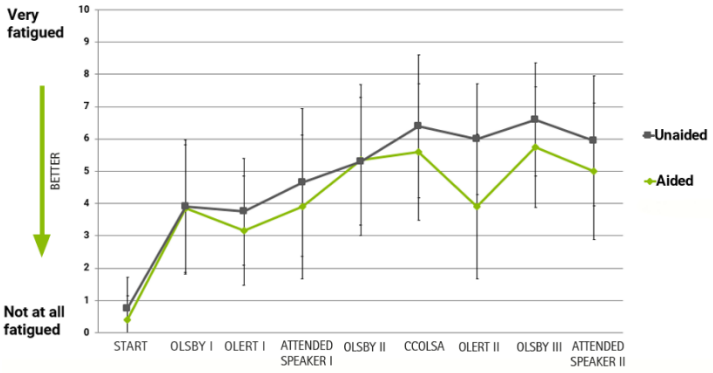

Figure 3. Subjective ratings of fatigue in aided and unaided conditions in each listening task across the acoustically compressed day. Ratings were measured on a scale (0=not fatigued and 10=very fatigued)

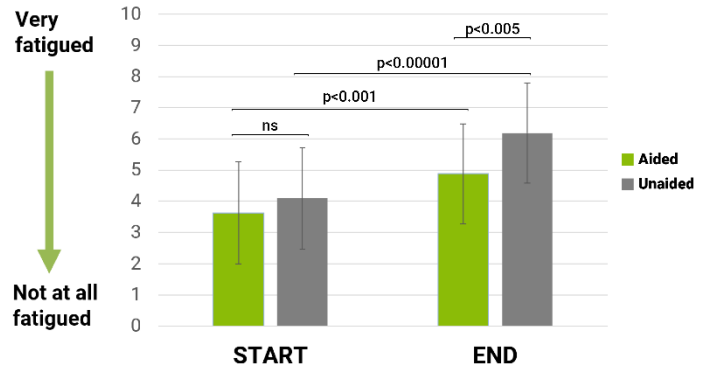

Figure 4. Average fatigue ratings associated with the first and second administrations of the OLSBY, OLERT and Attended Speaker tests for both the aided versus unaided condition. A significant difference in fatigue rating was seen in the beginning and end in both the aided ($p<0.01$) and unaided ($p<0.0001$) condition. A significant difference ($p<0.005$) was evident between the aided and unaided conditions at the end of the day.

Fig 5 compares the change in concentration index (Fig. 5A) and processing speed (Fig. 5B) from the d2-R test (Brickenkamp, 1962: a test of reaction time and attention), administered at the start (before) and end of (after) the time-compressed acoustic day. Results reveal that in the aided condition, there was both a reduction in overall concentration performance and a significant increase in processing speed over the course of the day ($p<0.05$), which might reflect a training effect. In contrast, in the unaided condition, there was no change in the concentration performance and in fact a decrease in the processing speed when comparing the first and second cohort of results. This suggests that the training effect seen in aided condition was either not present in the unaided condition or counteracted in the unaided condition due to the presence of fatigue.

Figure 5A

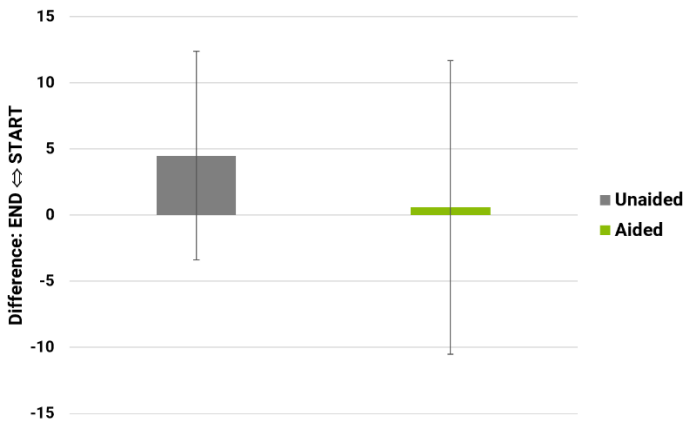

Figure 5B

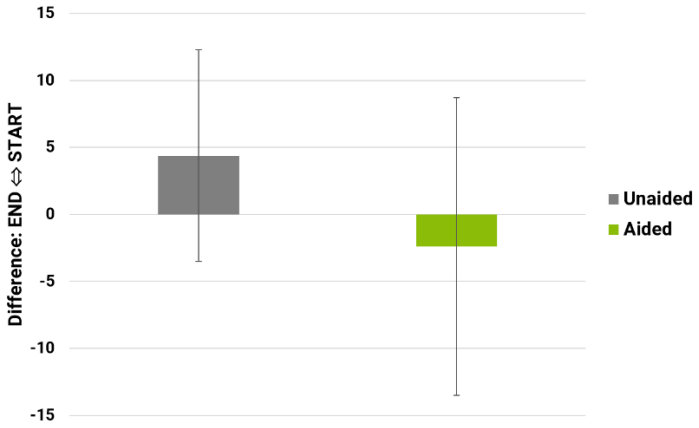

Figure 5. (A) - Relative concentration index comparing d2-R test from start to end of the acoustically compressed day. A positive number reflects higher concentration performance at the end of the day. **(B) -** illustrates the processing speed difference from start to end (s) in the d2-R test in the aided versus unaided condition. A positive number reflects higher processing speed and the end of the day. Differences observed between the aided and unaided condition are significant ($p<0.05$, CI 4.4).

Discussion

Capturing fatigue related to hearing loss can provide important insights into the overall 'activity limitation' hearing loss can have on the individual. The focus of this current study was to explore the impact of hearing technologies on listening effort and fatigue.
Intuitively, over the course of the time-compressed acoustic day, participant ratings of both concentration and subsequent fatigue increased in both the aided and unaided condition. However, both required concentration and fatigue ratings were significantly lower in the aided condition, consistent with the findings of previous studies showing hearing aids and their advanced features can reduce listening effort (Alhanbali et al., 2017; Hornsby, 2013; Bentler, 2008; Bess & Hornsby 2014; Noble & Gatehouse, 2006). The impact of technology on both objective performance and subjective ratings of listening

effort were well demonstrated by the OLERT test. OLERT results revealed significantly faster RTs and improved accuracy when using hearing aids and a TV connector versus the unaided condition in the evening scene (OLERT II). The objective results are consistent with other research showing improved speech intelligibility/accuracy when using wireless streaming to send the signal of interest to the hearing aids, such as remote microphone technology (Wolfe, et al., 2013). In addition, the faster RTs suggest the hearing aids and TV connector reduced the listening effort required for the task, which, in turn, is reflected in lower concentration required and subsequent fatigue ratings after the OLERT test (Fig 2 and 4).

In agreement with the findings of Hornsby (2013) subjective ratings of fatigue and required concentration increased over the acoustically time-compressed day. However, in contrast to the findings by Hornsby et al. (2013) who found that these differences in subjective ratings between the unaided and aided group were not significantly different by the end of the day, rated fatigue was significantly higher in the unaided versus aided condition and a significant difference in fatigue was evident between the beginning and the end of the day in both the unaided and aided groups. This suggests that as effort and fatigue grew throughout the time-compressed acoustic day amplification was beneficial in reducing fatigue.

The current study also utilized the d2-R test, which is a non-auditory measure of concentration. This was undertaken before and after the time-compressed acoustic day. Results showed that amplification led to significantly faster processing speed at the end of the day compared to the unaided condition. The improvement in processing speed and concentration cannot be attributed to a training effect as it wasn't seen when participants were unaided; rather these improvements are due to hearing aid use. This suggests that at the end of the time-compressed acoustic day, hearing aid use reduced fatigue, allowing greater cognitive resource to be available for the 2nd d2-R test.

The results of the present study demonstrate that subjects have poorer performance both objectively and subjectively when unaided. This suggests that when there is less 'effortful' listening, there is less opportunity cost, in the form of energy reserves, and consequently less reported fatigue. The overarching goal as audiologists is to improve the overall well-being of hearing aid wearers to ensure that they can maintain meaningful interactions with those around them.

Conclusion

This study was able to demonstrate that sustained speech processing leads to increased overall fatigue, however through the provision of hearing aids the amount of concentration needed and overall fatigue is reduced. Further, objective measures revealed that 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 improve overall well-being through enabling more efficient communication.

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David is the Commercial and Operations Director for Sonova Wholesale where he has worked for 13 years, and Director for Audiology for Sonova Australia and New Zealand. An interest in music and helping people made Audiology a natural career choice, and David graduated from the Master of Audiology course at University of Auckland, New Zealand in 1999. David worked clinically for 10 years, in both public and private settings, and in both NZ and overseas. David has a special interest in advanced hearing instrument and wireless communication technology, the selection of these based on client and family needs and supporting verification and evaluation of these features in the clinical setting.

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