Phonak
Field Study News

Less listening- and memory effort in noisy situations with StereoZoom

Electroencephalography (EEG) and subjective tests conducted at Hörzentrum Oldenburg found, that both listening effort and memory effort were reduced, when using a Phonak device with StereoZoom, compared to a competitive device with an alternative noise reduction microphone approach. The effect was particularly prominent in challenging listening situations where listening effort was reduced by 18%.

Axel Winneke, Matthias Latzel & Jennifer Appleton-Huber / July 2018

Introduction

Hearing loss is associated with listening effort. People suffering from hearing loss are constantly trying to 'fill in the blanks' of what they are listening to e.g. speech. This takes effort and can result in fatigue. Hearing aids attempt to improve speech intelligibility and therefore in turn, should reduce the amount of effort required in order to understand speech. The benefit of this is that the user should find the listening experience more enjoyable and be less fatigued.

The topic of measuring listening effort is of tremendous interest in the context of hearing aid fitting (Pichora-Fuller and Singh, 2006). This interesting approach evaluates hearing aids in listening situations, where stimuli are presented (also) at supra threshold intensities, where speech intelligibility may not differentiate performance or acceptance of different hearing aids/algorithms and/or their functionalities.

Therefore it is getting more and more popular to conduct hearing aid studies involving measurements of listening effort. One way to measure listening effort is to ask the hearing aid wearer to self-report the perceived listening effort. Alternatively, some objective methodologies exist, such as pupillometry, various electrophysiological measures, functional magnetic resonance imaging (fMRI), or skin-conductance (see overview by McGarrigle et al., 2014).

Several investigations have shown that EEG is a promising approach for measuring listening effort on a neural level. The hypothesis that listening effort can be linked to EEG activity is based on the idea that the brain operates on a limited amount of (neural) resources shared by sensory, perceptual and cognitive processes ("Limited resources theory". Related to this is the so called "effortfulness hypothesis" (Rabitt, 1968). This is related to the *limited resources hypothesis*: ". If signal processing is challenging (e.g. when listening to speech in a noisy environment), more processing resources have to be devoted to sensory encoding which leads to fewer resources available for higher level processing and listening becomes effortful".

This hypothesis was confirmed by a more recent study, which used EEG measurements to show the effect on listening effort, by varying the signal processing in hearing devices and/or the signal-to-noise ratio (SNR) (Winneke et al., 2016a,b).

The hearing aid algorithm, StereoZoom developed by Phonak uses binaural, directional microphone technology to create a narrow beam in especially challenging listening situations. In conversations with loud background noise, StereoZoom improves the SNR, resulting in improved speech intelligibility, better sound quality and higher suppression of noise (Latzel and Appleton, 2015; Phonak Field Study News, 2014). Other hearing aid manufacturers employ alternative approaches, which aim to improve speech understanding in noisy environments.

So far, the effect of StereoZoom on listening effort has been investigated using behavioral measures (e.g. Picou et al., 2014). The motivation of this study was to use an objective measure (EEG) to show differences in listening effort when using different hearing aid algorithms under the same environmental conditions. There were two objectives to the study.

1) Comparison of the listening effort of two programs realized in Phonak hearing devices:
   Speech in Loud Noise (Phonak SPILN): using StereoZoom (directional microphone technology) and
   Calm Situation (Phonak Calm): using the microphone setting Real Ear Sound (RES, an omnidirectional microphone setting which simulates the directionality of the pinna)
2) Comparison of the listening effort of the Phonak SPILN program with the approach from a competitor.
   Speech in Loud Noise (Phonak SPILN): using the directional microphone technology, StereoZoom
   Competitor (Comp Noise): using an alternative approach to process speech in noise

Methodology

Participants

A total of 20 experienced hearing aid users with mild to moderate hearing loss (figure 1) participated in the study. The average age of the participants was 70.90 years (SD = 7.28). 12 participants were female, 8 were male. Each participant was fitted with two sets of hearing aids: Audéo B90-312 from Phonak and a competitor hearing aid, both with closed coupling with silicone based earmoulds (SlimTips).

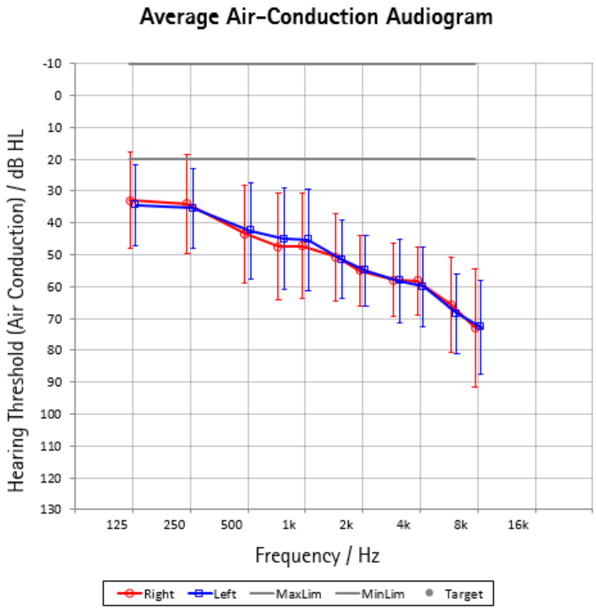

Figure 1. Average hearing loss of the 20 participants. Minimum and maximum hearing loss values are also shown.

Test setup

The noise signal was a diffuse cafeteria noise at a constant level of 65 dB SPL played via loud speakers positioned at 30°, 60°, 90°, 120°, 150°, 180°, 210, 240°, 270°, 300°, 330°.

SNR conditions

SNR was modified by adjusting the level of speech signal which was presented via a loudspeaker facing the participant at 0°, until the SRT50 was determined for each participant. Based on this individual SRT50 the High SNR and Low SNR conditions were defined individually as follows:

High SNR = SRT50 + 3 dB + 4 dB
Low SNR = SRT50 + 3 dB

Test conditions

The experiment included 8 conditions in a 2 x 2 x 2 design with the following factors

- SNR: High SNR versus Low SNR
- Hearing device: Phonak Audéo B90-312 versus Competitor
- Program:
  Phonak SPILN versus PHONAK Calm
  and
  Comp Noise versus Comp Calm (competitor setting for quiet environments

Test paradigm

The speech material used in this study was taken from the OLSA sentence matrix test material (Wagener & Kollmeier, 1999). Based on these sentences, a Word-Recall-Task was developed. Participants heard two sentences consecutively and they had to recall either the names, the numbers, or the objects they had heard (i.e. memory task). The answers were given via touchscreen. The resulting depending variable was the percentage correctly recalled sentence parts (i.e. accuracy).

After each block (8 x 2 sentences = 16 sentences) participants were asked to rate their experience of listening effort and memory effort (i.e. how effortful it was to recall the items). Answers could be given based on a 13 point scale adapted from the ACALES scale (Krüger et al., 2017) via touch screen.

The conditions were presented in blocks in a randomized sequence: Half of the participants started with the Phonak devices and the other half with the competitor devices.

Brain activity was recorded using a 24 channel wireless Smarting EEG system (mBrainTrain, Belgrade, Serbia) with 24 electrodes mounted into a custom-made elastic EEG cap (EasyCap, Herrsching, Germany) and arranged according to the International 10–20 system (Jasper, 1958). While participants were listening and recalling the OLSA sentences, the EEG was recorded at a sampling rate of 500 Hz, with a low-pass filter of 250 Hz.

An offline analysis of the EEG signal was conducted. The recordings were epoched into 2500 ms time windows around the onset of each OLSA sentence. A spectral density analysis between 3 and 25 Hz was conducted in these time windows. The focus was placed on the EEG alpha frequency band (8 – 12 Hz).

Results

Analysis of EEG recordings lead to two participants being excluded from the EEG data sample. This was due to poor impedance values during recording for one participant and loss of data, due to lost Bluetooth connection for the other participant. This resulted in a sample size of 18 for EEG recording analysis.

The objective measure of response accuracy (percentage of correct answers) showed that the SNR conditions were well-chosen, leading to good speech intelligibility so that the accuracy was between 70 and 90% for (mostly) all settings.

Subjective listening effort was rated for each condition. For Phonak, when in a poor SNR, listening effort was rated statistically lower (19%) when Phonak SPILN was used, as opposed to Phonak Calm. For the competitor, no difference in listening effort was reported when using Comp Noise as opposed to Comp Calm. When the devices were compared directly with one another (figure 2), listening effort was rated significantly lower (18%) with Phonak SPILN than with Comp Noise.

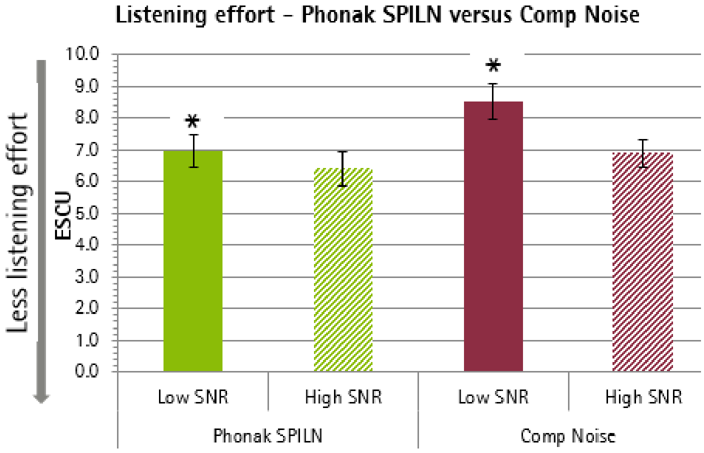

Figure 2. Average subjective listening effort rating (Estimated Scaling Units (ESCU)) with standard error bars for Phonak SPILN and Comp Noise in high and low SNR conditions). * = significant difference

Subjective memory effort was also rated for each condition. Listening effort is a cognitive activity at a lower stage in the brain, whereas the memory effect is somewhat higher and later. A correlation analysis could show that the participants rated the listening effort differently than the memory effort, suggesting that the participants were able to differentiate between both dimensions.

The memory effort was rated significantly lower with Phonak SPILN than with Phonak Calm whereas no difference was reported between the Comp Noise and Comp Calm setting. When the devices were compared directly with one another (figure 3) memory effort was also rated significantly lower for Phonak SPILN than for Comp Noise.

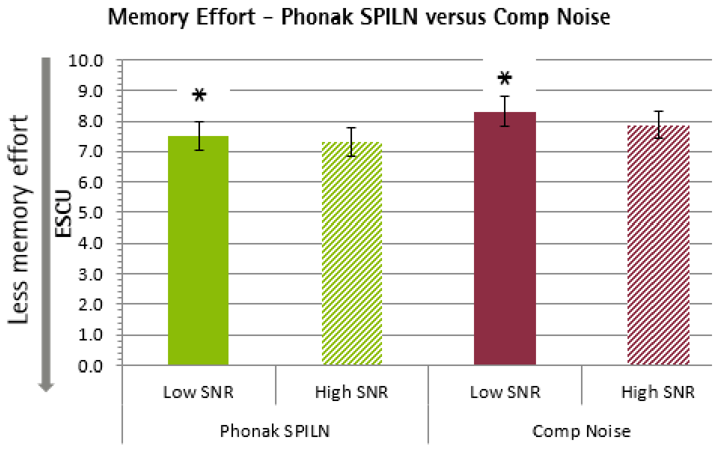

Figure 3. Average subjective memory effort rating (Estimated Scaling Units (ESCU)) with standard error bars for Phonak SPILN and Competitor Comp in high and low SNR conditions. * = significant difference

These results show that the effort required to listen and to understand speech and also to keep this information in the memory, is higher when using Comp Noise in comparison to Phonak SPILN.

EEG analysis (figure 4) showed that the alpha spectral density (8-11 Hz) for the Phonak SPILN setting was lower than for the Comp Noise regardless of SNR. Lower alpha band activity with Phonak SPILN indicates lower listening effort compared to the competitor conditions, which supports the findings of the behavioral data .

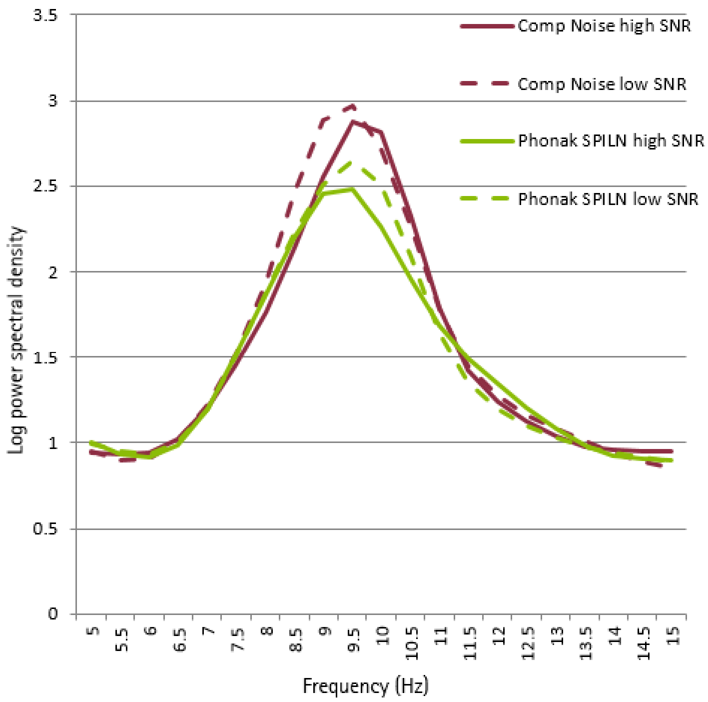

Figure 4. Average spectral density values values (averaged across time and electrodes C3, C4, CP5, CP6, P3, P4.) between 5 and 15 Hz for Phonak SPILN and Comp Noise in high SNR und low SNR. The image shows that the activity is higher for the competitor than for Phonak in both low SNR and high SNR conditions.

Discussion and conclusion

Subjective listening effort is lower for Phonak SPILN than Phonak Calm, particularly when SNR is at a lower level. The results of the EEG data analysis (alpha band activity) are consistent with the subjective data, because the alpha activity when using Phonak SPILN is significantly lower than when using Phonak Calm independent of SNR. The effect of StereoZoom is more prominent noise suppression. Thereby the speech signal is easier to understand, because with StereoZoom in Phonak SPILN, less of the interfering cafeteria noise has to be suppressed by the brain (shared resources hypothesis). This is reflected in a reduction in alpha activity for Phonak SPILN as compared to Phonak Calm. The results of the EEG data analysis indicate a reduction of listening effort, which is evident also on a neurophysiological level (Strauss, 2014).

The results regarding the comparison of Phonak SPILN and Comp Noise, resemble the results concerning the comparison of Phonak SPILN and Phonak Calm. The subjective listening effort and memory effort are lower for Phonak SPILN than for Comp Noise, particularly in lower SNR conditions. Again, the results of the EEG data analysis (alpha spectral density) align with the subjective data, because alpha activity is significantly lower for Phonak SPILN compared to Comp Noise independent of SNR. This could indicate that noise suppression in StereoZoom has a larger effect than the approach activated with Comp Noise, which in turn causes listening effort, both subjectively as well as objectively, to be smaller for Phonak SPILN, compared to Comp Noise.

When using individual SNR values to guarantee sufficient speech intelligibility in all conditions, there were no significant differences between Phonak SPILN and Comp Noise, with respect to response accuracy (% correctly recalled words). The elevated listening effort for Comp Noise may be a potential indicator of compensatory processes, which are necessary to maintain a good level of cognitive performance. In other words, when using Comp Noise, participants have to “invest” more (neural) resources, to perform at the same level as with Phonak SPILN with StereoZoom. This increase in investment reveals itself as an increase in listening effort – which has been proven subjectively as well as neurophysiologically.

EEG constitutes a useful and informative method to objectively assess and quantify listening effort and in this case, revealed a reduced listening effort for StereoZoom over its competitor, particularly in noisy environments.

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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.

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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. Since 2012 he has been working as the Clinical Research Manager for Phonak AG, Switzerland

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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 Technical Editorial Manager at Phonak Headquarters.