

Reduced listening effort in noise with StereoZoom in Naída

Electroencephalography (EEG) and subjective tests conducted at Hörzentrum Oldenburg with participants with severe hearing loss found that listening effort was reduced, when using a Phonak device with StereoZoom, compared to Real Ear Sound.

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Introduction

Hearing loss is associated with increased 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 can take effort and can result in fatigue (Hornsby, 2013). 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. However, in these situations, different

hearing aids/algorithms or their functionalities could still result in more or less 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 electroencephalography (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. This is commonly referred to as the "Limited resources theory" (Kahneman, 1973). Related to this is the so called "effortfulness hypothesis" (Rabitt, 1968) which indicates that if signal processing is challenging (e.g. when listening to speech in a noisy environment or due to a

hearing impairment), more processing resources have to be devoted to sensory encoding. This leads to fewer resources available for higher level processing and listening becomes effortful.

This hypothesis was confirmed by recent studies, 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). Lower listening effort was reflected by lower alpha activity in the EEG recording (Winneke et al., 2016; Winneke et al., 2018 a,b,c).

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; Appleton-Huber and König, 2014, Latzel & Appleton-Huber, 2018).

Winneke et al. (2018a) found that subjective listening effort in noisy situations was reduced by 19% when using StereoZoom compared to Real Ear Sound (RES, a monaural, directional microphone setting which simulates the natural directionality of the pinna). EEG analysis found that alpha band activity was significantly lower when using StereoZoom than when using RES. These measurements were conducted with hearing aid users with a mild to moderate hearing loss, fitted with Phonak Audéo B90-312 hearing aids.

Objective

The goal of this study was to assess whether a binaural directional microphone (StereoZoom) and a monaural microphone (RES) differ from each other in terms of their effect on listening effort in individuals with severe hearing impairments. This was measured objectively via analysis of the EEG alpha frequency band (9 – 12 Hz) (see Winneke et al., 2018 b,c) and subjectively via asking participants to rate the listening effort on a scale (Krüger et al. 2017).

Specifically the aim was to evaluate whether StereoZoom in Naída hearing aids is linked to a reduction in listening effort in a speech in noise situation compared to the hearing aid feature RES.

Methodology

Participants

A total of 20 experienced hearing aid users participated in the study. The average age of the participants was 65.75 years (Standard Deviation (SD) = 14.07). 9 participants were women, 11 men. Participants had a severe hearing loss (criterion: minimum average of 67 dB HL in the better ear; see audiogram in figure 1).

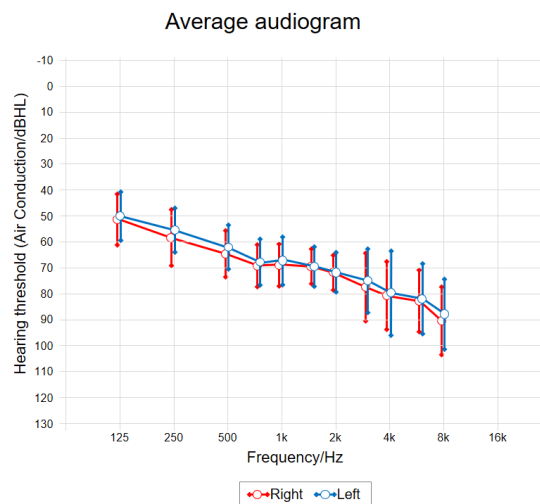


Figure 1. Average air conduction (AC) audiogram of the 20 study participants. Pure Tone Average Air Conduction (PTA-AC): right: mean = 71.4; SD = 5.3; left: m = 70.38; SD = 6.6).

Equipment

Each participant was fitted with Naída B90-SP (equivalent in performance to Naída M90-SP for the specific aspects tested in this study) hearing aids from Phonak. The participants own earmolds were used. If the earmold looked old and ill-fitting, new earmolds were made, with the same venting as the participants' own earmolds.

Test setup

The noise signal was a diffuse cafeteria noise, presented at a fixed intensity of 67 dB SPL via loud speakers positioned in a circle around the participant 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 individually for each participant. Based on this individual SRT50 (indSRT50) the High SNR, medium SNR and Low SNR conditions were defined as follows (for more information see Winneke et al. (2019)):

High SNR = indSRT50 + 10 dB

Medium SNR = indSRT50 + 6.5 dB

Low SNR = indSRT50 + 3 dB

Test conditions

The experiment included 6 conditions in a 3 x 2 design with the following factors:

SNR: High SNR versus Medium SNR versus Low SNR

Program: StereoZoom versus RES

Test paradigm

The speech material used in this study was taken from the OLSA sentence matrix test material (Wagener & Kollmeier, 1999). All OLSA sentences are structured identically and consist of five word categories (name, verb, number, adjective and object). The sentences are constructed in a random fashion based on a database that contains 10 instances for each category. Participants heard three sentences (a triplet) and were subsequently asked to rate their perceived listening effort via a touch screen. The scale ranged from 1 (effortless) to 14 (only noise) based on the ACALES procedure (Krüger et al., 2017).

Whereas SNR was randomized the two different programs were presented in blocks in a counterbalanced sequence. That is, half of the participants started with StereoZoom and the other half with RES. Each block consisted of 30 triplets (i.e. 90 sentences) with 10 triplets for each of the three SNRs.

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 to 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 (9 – 12 Hz).

Results

Subjective listening effort ratings are visualized in figure 2. This shows that listening with RES is always rated as needing more effort than listening with StereoZoom (statistically significant $p < .001$).

When using StereoZoom for the most difficult signal-to-noise-ratio of individual SRT plus 3dB, this results in an improved subjective rating of listening effort in noise equal to an improvement in signal-to-noise ratio of 3.5 dB when using RES. At 3 dB SNR the listening effort rating for RES is 9.6 and for StereoZoom is 7.3. This corresponds to 24% less listening effort in noise with StereoZoom compared to RES $((9.6-7.3)/9.6*100 = 23.96\%)$.

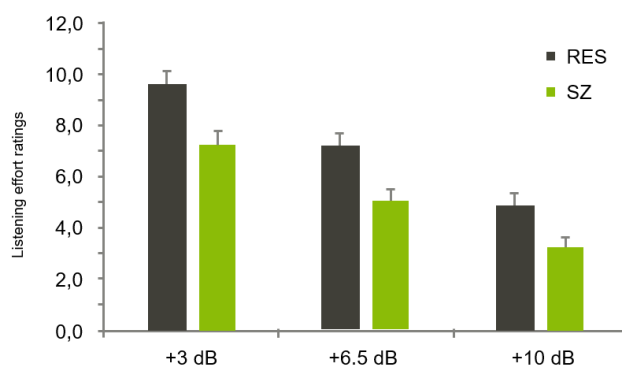


Figure 2. Average subjective listening effort ratings for StereoZoom (SZ) and RES for three SNR conditions (SRT50 +3 dB, +6.5 dB, +10 dB). Error bars depict standard errors. Listening effort rating in ESCU = Effort Scaling Categorical Unit

Figure 3 shows the average alpha spectral density values for the three SNR conditions (individual SRT plus 3 dB, 6.5 dB and 10 dB) and the two programs (RES and StereoZoom). Due to poor EEG data quality, EEG data of three participants were excluded from analysis, resulting in a sample size of 17.

It shows that the power of the EEG response is lower for StereoZoom than for RES and the difference is statistically significant for all SNRs. These results indicate reduced cognitive effort when using StereoZoom. In fact, the graph indicates that for the easiest signal-to-noise ratio (10 dB), the alpha band activity for RES (open circle at +10 dB) is about the same as the alpha band activity for StereoZoom at the most difficult SNR (closed circle at +3 dB). In other words, the alpha band activity for StereoZoom in noise was comparable to the activity for RES at an SNR of +7 dB. This suggests that the brain activity linked to listening effort is lower for StereoZoom than for RES.

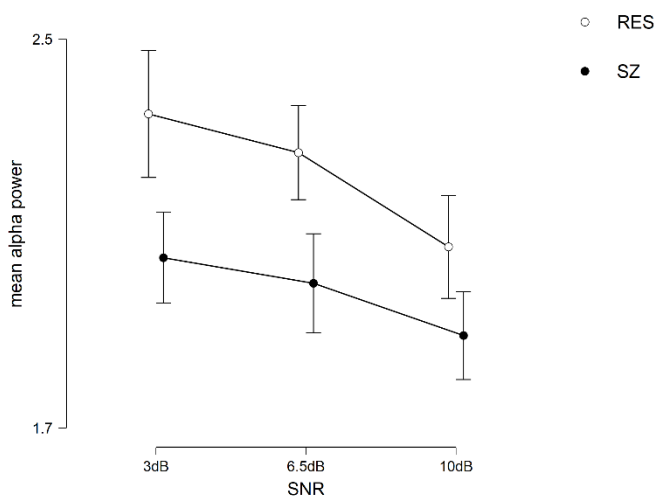


Figure 3. Average alpha spectral density values for three SNR conditions and program. Averaged across participants and across frequency range 9 – 12 Hz. Error bars depict stand errors.

Conclusion

Previous research with participants with a mild-moderate hearing loss, found a reduction in listening effort in noise when using StereoZoom over RES. This was found to be the case both subjectively and also objectively, via EEG analysis.

This current study found very similar results for participants with severe hearing loss. Subjective listening effort was found to be lower for StereoZoom than for RES, particularly when SNR is at a lower level (more difficult listening situation). The results of the EEG data analysis (alpha band activity) are consistent with the subjective data, because the alpha activity when using StereoZoom is significantly lower than when using RES independent of SNR.

The effect of StereoZoom is more prominent noise suppression. Thereby the speech signal is easier to understand, because with StereoZoom, less of the interfering cafeteria noise has to be suppressed by the brain (limited resources theory). This is reflected in a reduction in alpha activity for StereoZoom as compared to RES. The results of the EEG data analysis indicate a reduction of listening effort, which is evident also on a neurophysiological level (Strauss, 2014).

References

Appleton-Huber, J., & König, G. (2014). Improvement in speech intelligibility and subjective benefit with binaural beamformer technology. *Hearing Review*, 21(11), 40-42.

Hornsby, B. W. (2013). The effects of hearing aid use on listening effort and mental fatigue associated with sustained speech processing demands. *Ear and Hearing*, 35(5), 523-534.

Jasper, H. H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, 10, 371-375.

Kahneman, D. (1973). *Attention and Effort*. Englewood Cliffs, NJ: Prentice-Hall

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., & Appleton-Huber, J. (2015). StereoZoom - Adaptive behavior improves speech intelligibility, sound quality and suppression of noise. *Phonak Field Study News*, retrieved from www.phonakpro.com/evidence, accessed November 5th 2019.

Latzel, M., & Appleton-Huber, J. (2018). StereoZoom provides benefit to those with severe hearing loss. *Phonak Field Study News*, retrieved from www.phonakpro.com/evidence accessed November 5th, 2019.

McGarrigle, R., Munro, K. J., Dawes, P., et al. (2014). Listening effort and fatigue: what exactly are we measuring? A British Society of Audiology Cognition in Hearing Special Interest Group 'white paper'. *International Journal of Audiology*, 53, 433-440.

Pichora-Fuller, M., Singh, G. (2006). Effects of age on auditory and cognitive processing: implications for hearing aid fitting and audiological rehabilitation. *Trends in Amplification*, 10(1), 29-59.

Rabbitt, P. (1968). Channel-capacity, intelligibility and immediate memory. *Quarterly Journal of Experimental Psychology*, 20, 241-248.

Strauss, A., Wöstmann, M., Obleser, J. (2014). Cortical alpha oscillations as a tool for auditory selective inhibition. *Front Human Neuroscience*, 8(350), 1-7.

Wagener, K., Brand, T., & Kollmeier, B. (1999). Entwicklung und Evaluation eines Satztests für die deutsche Sprache II: Optimierung des Oldenburger Satztests. *Zeitschrift für Audiologie* (38), S. 44-56.

Winneke, A., Meis, M., Wellmann, J., Bruns, T., Rahner, S., Rannies, J., Wallhoff, F., & Goetze, S. (2016). Neuroergonomic assessment of listening effort in older call center employees. Proceedings of the 9th AAL Kongress, Frankfurt/Main.

Winneke, A., Latzel, M., & Appleton-Huber, J. (2018a). Less listening – and memory effort in noisy situations with StereoZoom. Phonak Field Study News, retrieved from www.phonakpro.com/evidence, accessed October 31st, 2019.

Winneke, A., Schulte, M., Vormann, M., & Latzel, M. (2018b). Spatial noise processing in hearing aids modulates neural markers linked to listening effort: an EEG study. *Audiology Online*, 1-27.

Winneke, A., Vos, M. D., Wagener, K. C., Derleth, P., Latzel, M., Appell, J., & Wallhoff, F. (2018c). Listening effort and EEG as measures of performance of modern hearing aid algorithms. *Audiology Online*, 1-13.

Winneke, A., Schulte, M., Vormann, M., & Latzel, M. (2019). The effect of directional microphone technology in hearing aids on neural correlates of listening and memory effort: an EEG study. *Trends in Hearing*. Manuscript submitted.

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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

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Michael Schulte has been with Hörzentrum Oldenburg GmbH, Germany since 2004, where he has been responsible for audiological studies in publicly funded projects as well as in cooperation with the industry. In 2002, he received his Ph.D. from the Biomagnetism

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Study coordinator



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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