Phonak
Field Study News

Better memory recall and less memory effort in noise with StereoZoom in Naída

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

Axel Winneke, Michael Schulte, Matthias Latzel & Jennifer Appleton-Huber, February 2020

Introduction

Speech perception can be challenging and effortful in noisy environments especially for individuals with impaired hearing, even when fitted with hearing aids (CHABA - Committee on Hearing and Bioacoustics, 1988; McCoy et al., 2005; Klink et al., 2012). Impaired speech intelligibility due to background noise or impaired hearing function requires mental effort to compensate for the impoverished signal quality, which in turn can impair cognitive performance i.e. compromises the amount of cognitive resources available for performing other tasks at the same time (Schneider and Pichora-Fuller, 2000).

The hearing aid algorithm, StereoZoom developed by Phonak to support binaural hearing, uses directional microphone technology to create a narrow beam by processing the four microphone signals when bilaterally fitted with hearing aids. In conversations with loud background noise, StereoZoom improves the signal-to-noise ratio (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).

Several investigations have shown that electroencephalography (EEG) is a promising approach for measuring listening- and memory effort on a neural level. The hypothesis that listening- and memory 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 also recalling information becomes effortful (memory effort).

This hypothesis was confirmed by recent studies, which used EEG measurements to investigate 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). Winneke et al. 2018 also indicated a decrease in subjective memory effort when using StereoZoom over Real Ear Sound (RES). This data was obtained by asking participants to rate the effort needed to recall words from sentences which they had just heard.

To follow-up on this finding, the goal of this current study was to investigate whether StereoZoom in Naída is linked to increased memory capacity in a speech in noise situation, compared to the hearing aid feature Real Ear-Sound. Both a subjective measure and the objective, physiological EEG measure were used.

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 (criterium: minimum average of 61 dB HL at the frequencies of 500, 1000, 2000 and 4000 Hz in the better ear; see audiogram in figure 1).

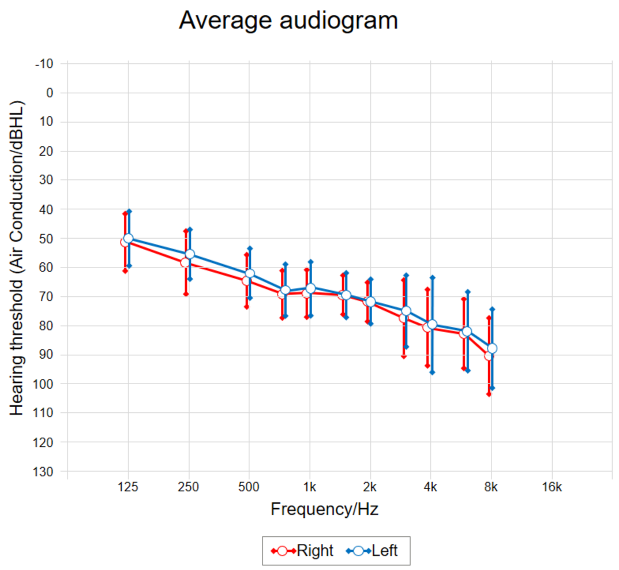

Figure 1. Average air conduction (AC) audiogram of the 20 study participants. Pure Tone Average Air Conduction (PTA-AC): right: mean = 71; SD = 5.3; left: m = 70; SD = 6.6).

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° and 330°.

SNR conditions

SNR was modified by adjusting the level of the speech signal which was presented via a loudspeaker facing the participant at 0°, until the SRT50 was determined individually for each participant using Naída B90-SP in the RES mode. Based on this individual SRT50 (indSRT50) sentences were presented at the individual level of indSRT50 + 10 dB (for more information see Winneke et al. (2019)).

Test conditions

The experiment included 4 conditions in a 2x2 design with the following factors:
Sentence predictability: low versus high
Program: StereoZoom versus RES

Test paradigm

The speech material used in this study consisted of sentences of the Basler sentence test (Tschopp et al., 2001). The participants' task was to repeat the sentence they heard and remember the last word of each sentence. After four sentences, the participants had to recall the final words of the last four sentences. Half of the sentences had final words that were highly predictable based on the preceding context whereas the other half had final words with low predictability. Sentence length was on average 2.4 seconds. The inter-stimulus-interval between sentences varied depending on how long participants took to repeat the sentence. The prompt to recall the final words appeared 2 seconds after the final sentence was repeated. The investigator scored the number of correctly repeated words per sentence as well as the number of correctly recalled final words. It was crucial that participants understood almost every word because otherwise it would not be possible to differentiate whether performance in the memory task was due to memory processes or speech intelligibility. Therefore a screening procedure was used where only participants who recognized 55 words (or more) out of 60 were included in the study. This corresponds to a speech intelligibility of 92%. All 20 participants met this criterion.

The experiment was split up into two blocks, one for each hearing aid program. The sequence of blocks was counterbalanced across participants to control for sequence effects. Each block contained 24 high predictable (HP) and 24 low predictable (LP) sentences each divided into 6 trials of four sentences. Trial sequence was randomized and each trial contained either high or low predictability sentences. After each block, participants were asked to rate their subjectively experienced memory effort (i.e. how effortful it was to recall the items) on a scale ranging from 1 'effortless' to 13 'extremely effortful'.

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 Basler 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 divided into 2500 ms time windows around the onset of each Basler 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

Simple comparisons (paired t-tests) regarding the subjective memory effort (i.e. "How effortful was it to remember the words?") on a scale from 1-13 indicated significantly lower scores for StereoZoom compared to RES ($p < .01$; see figure 2).

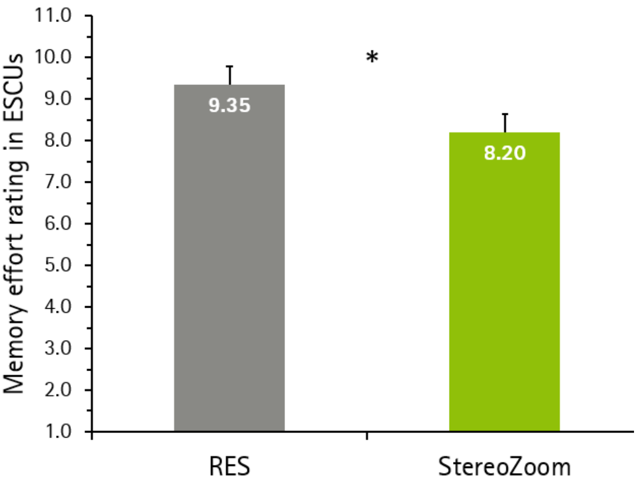

Figure 2. Mean subjective memory effort scores averaged across participants and predictability (high and low predictable sentences) for RES (gray) and SZ (green). Error bars depict standard errors. Listening effort rating in ESCU = Effort Scaling Categorical Unit. * = significant difference.

Simple comparisons (paired t-tests) between StereoZoom and RES were conducted separately for the three behavioral dependent variables of 1) percent correctly understood words (i.e. speech intelligibility) and 2) percent correctly recalled final words. The analysis indicated significant differences between StereoZoom and RES for both measures ($p < .01$; see figure 3). As can be seen in figure 3 the overall intelligibility was very high, but higher for StereoZoom than RES. Also, more words were recalled during StereoZoom than RES.

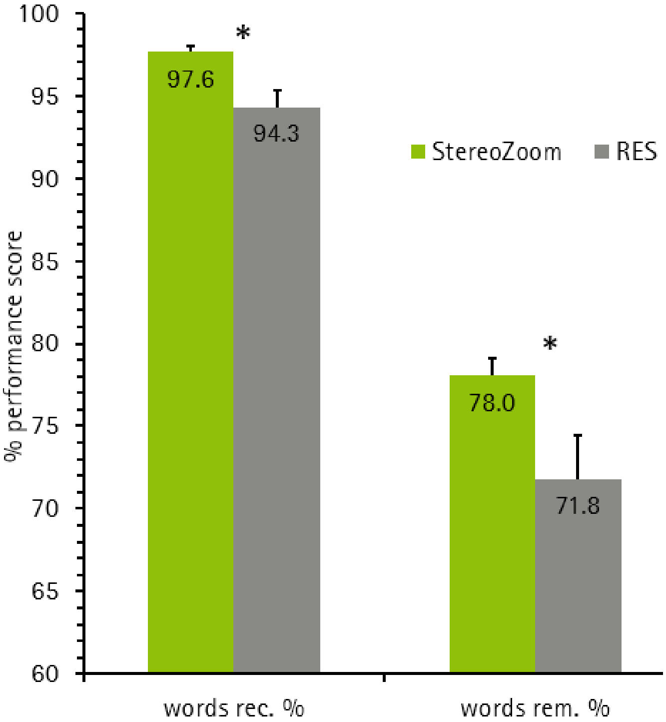

Figure 3. Mean behavioral performance scores (words recognized & words remembered) averaged across participants and predictability (high and low predictable sentences) for RES (gray) and StereoZoom (green). Error bars depict standard errors. * = significant difference.

To also consider predictability, a 2 (program (SZ vs. RES)) x 2 (predictability (high predictability vs. low predictability)) repeated measures ANOVA on the two behavioral measures was run separately. Low predictability was the more difficult condition than high predictability. For all three measures, a main effect of program and a main effect of predictability were revealed but no significant interaction was detected. The results indicate better speech recognition and memory performance for StereoZoom than RES and better recognition and memory performance for high predictability than low predictability (see figure 4).

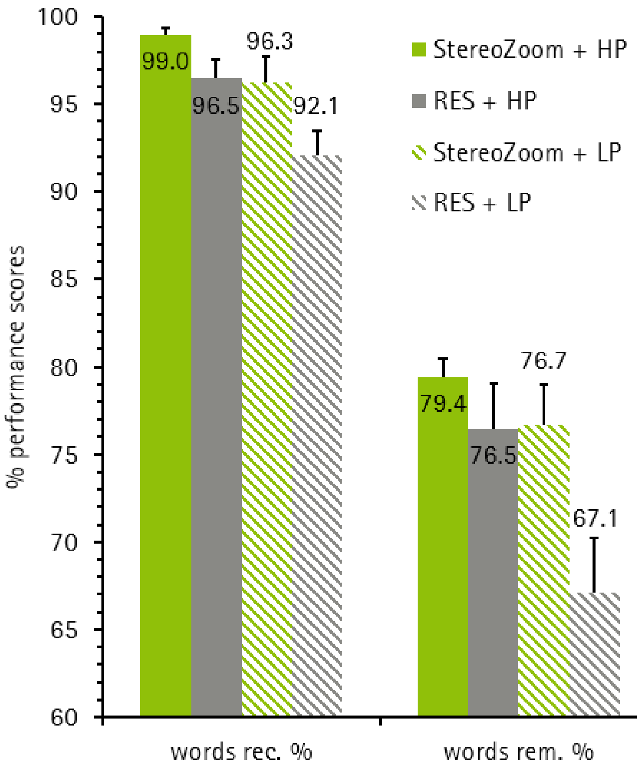

Figure 4. Mean behavioral performance scores (words recognized & words remembered) averaged across participants separated for predictability (high (solid) and low (striped) predictable sentences) for RES (gray) and StereoZoom (green). Error bars depict standard errors.

For words which have low predictability, StereoZoom improves recall in noise by 10% (statistically significant) compared to RES.

Figure 5 shows the average alpha spectral density values for the two programs (RES and StereoZoom) and the two sentence predictability levels. It shows that the power of the EEG response is lower for StereoZoom than for RES and this effect is more pronounced when listening to more difficult (low predictability) sentences. These results indicate reduced memory effort when using StereoZoom versus RES, particularly when listening to less predictable sentences.

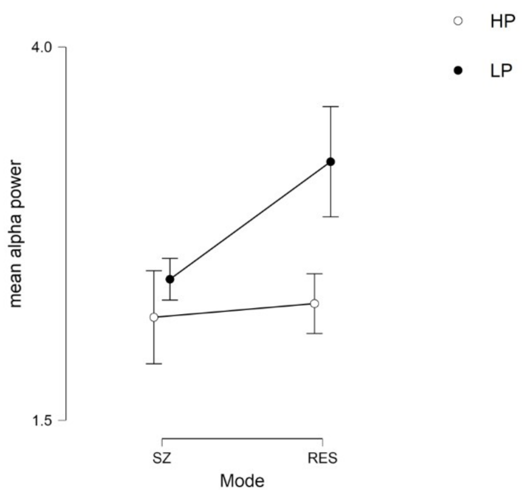

Figure 5. Average alpha spectral density values for StereoZoom and RES separated by high- (HP, white circles) and low- (LP, black circles) predictability sentences. Averaged across participants and across frequency range 9–12 Hz. Error bars depict standard errors.

Conclusion

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

This current study found very similar results for participants with severe hearing loss. The results of this study show that on a subjective level, the experienced memory effort is lower when using StereoZoom over RES in a noisy environment. Objective measures also found that recalling words in noise is statistically improved when using StereoZoom over RES. This is also reflected in a reduction in EEG alpha activity for StereoZoom as compared to RES which indicates a reduction in memory effort. Both the memory recall test and the EEG analysis revealed that this effect was more pronounced when listening to more difficult sentences (lower predictability).

These results can be explained by the more prominent noise suppression of StereoZoom compared to RES. This makes the speech signal easier to understand, because with StereoZoom, less of the interfering noise has to be suppressed by the brain (limited resources theory). This can then lead to more cognitive resources being available during the retrieval phase.

This study with Naída indicates that not only those with mild-moderate hearing loss, but also those with severe hearing loss, can benefit from better memory recall and less (reduced) memory effort when using StereoZoom compared to RES.

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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.

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 Centre at the Institute of Experimental Audiology, University of Münster, Germany. From 2002 to 2003, he worked as a postdoc at the F.C. Donders Centre for Cognitive Neuroimaging, Nijmegen, Netherlands. Michael Schulte's research interest is in the evaluation of hearing systems with a special focus on 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 works as the Clinical Research Manager for Sonova 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.