WHITEPAPER
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Opn Clinical Evidence

INTRODUCTION

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This whitepaper presents a summary of the clinical studies investigating the end-user benefits of the new signal processing introduced in Oticon Opn on cognitive effort, memory recall, and speech recognition performance. Among the new signal processing, a new noise reduction algorithm named OpenSound Navigator (OSN), is introduced. It belongs to a new technology class of its own, the Multiple Speaker Access Technology (MSAT), as it uses different principles than current directionality and noise reduction systems (Le Goff et al. 2016).

Speech recognition performance is a well-established measure of the performance of hearing-aids and it was therefore part of the investigations on the performance of Opn. In a traditional speech-recognition test, the task of the participants is however only partly representing the complex interactions of daily conversations and recognition thresholds are often negative signal-to-noise ratios (SNRs) that are much lower than those found in daily environments (Smeds et al. 2015). To overcome these limitations, two studies on cognitive effort and memory recall were conducted to assess the cognitive benefits of OSN in acoustical environments with positive SNRs (Lunner et al. 2016). Each study is presented in a separate section authored by its respective main investigator and an interpretation of the findings is proposed in the last section.

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Cognitive effort

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The objective of the study was to evaluate the potential benefits of the noise reduction (NR) algorithm applied in hearing-aids on the cognitive effort in people with hearing impairment. Cognitive effort was investigated in a speech recognition task by measuring the participant's pupil dilation. Pupillometry is a commonly used method for assessing the effort involved in performing a task, such as speech recognition in background noise (see e.g. Kramer et al., 1997). It is assumed that if the processing demands increase during speech reception, for instance due to background noise, an increase in cognitive effort is reflected in an increased pupil dilation.

Experiment

The effect of NR on the participant's effort was tested while participants wore actual hearing aids with their respective NR algorithm. The benefit of NR was measured with two different hearing aids, Alta 2 Pro and Opn. While Opn used the new NR algorithm OSN, Alta 2 pro used a more conventional slow-acting, directionality-based system.

Twenty-four hearing-impaired listeners, with an average age of 59 years (ranging from 35 to 80 years) participated in the experiment. The participants had mild to moderate-to-severe symmetrical sensorineural hearing loss (PTA4 ranging from 34 to 70 dB HL with an average of 47 dB HL).

The participants were asked to listen to the Danish HINT sentences presented in noise and to repeat back the sentence after presentation. Participants performed two test-lists, one for each hearing-aid condition, containing 25 trials each. The noise consisted of a 4-talker babble presented in a spatial loudspeaker setup at +/-90° and +/-150° - see figure 1. In addition, an unmodulated speech-shaped noise (SSN) was added in order to simulate a diffuse background noise. The SSN was added to the two competing talker presented +/-150°, and were presented with an SNR of -1.8 dB leading to an overall SNR of -4 dB of the speech and the 4-talker-babble in the unmodulated noise. Pupil dilation was recorded during the recognition task with an eye-tracker system (iView X RED System, Senso -Motoric Instruments).

The overall level of the speech was 70 dB SPL, and the SNR was adjusted for each participant to ensure 95% correct speech recognition (mean=7.1 dB SNR, SD=2.3). The speech recognition had therefore reached a ceiling, but the NR algorithms were expected to facilitate speech recognition, i.e., to reduce the cognitive effort involved in speech recognition.

Figure 1: Spatial setup of the loudspeakers: Four loudspeaker are positioned at the side and the back of the participants, i.e. at +/-90° and +/-150° to present the 4 competing talkers (one competing talker per loudspeaker) and noise. The target loudspeaker is positioned in the front at 0°. The distance between the camera and the participants was about 60 cm. The experiment was performed in a sound-proof booth.

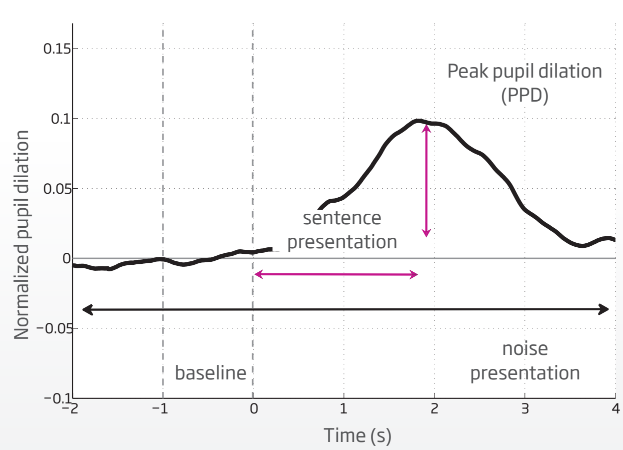

Figure 2: Example of normalised pupil curve averaged across all subjects. Pupil size is normalised according to the baseline where the noise was present in isolation.

Analysis and Results

Pupil data were measured for 25 trials for each participant. Data of the first five trials were removed from the analysis to eliminate training effects. Among the remaining trials, those consisting of blinks and movements for more than 20% of the data were excluded (two participants excluded). For the remaining trials, eye-blinks were removed by a linear interpolation and furthermore a smoothing filter was passed over the de-blinked trials to remove any high-frequency artifacts.

All remaining traces were baseline corrected by subtracting a baseline value. This value was estimated by the mean pupil size within the 1 second previous to the onset of the sentence, i.e. when the participant listened to the noise alone. The peak pupil dilation (PPD) was calculated for each participant and each hearing-aid condition. The PPD is defined as the maximum pupil dilation during the time interval between sentence onset and the noise offset (see Figure 2).

Results depicted in figure 3 show that the average PPD was 0.93mm for Alta 2 pro and 0.69mm for Opn. A T-test revealed significant differences between both PPDs (t=2.2, p=0.04) indicating a significant reduction in PPD when applying NR in Opn compared to Alta 2.

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Memory recall

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Noise has a negative impact on speech understanding and remembering heard speech, which can be mitigated by aggressive noise reduction (Ng et al. 2013, 2015). The present study aimed to measure cognitive benefit (in terms of recall performance) of the NR algorithm implemented in Opn hearing aids, OSN. Moreover, this study aimed to compare cognitive benefit at signal-to-noise ratios (SNRs) predicting 95% and 70% speech intelligibility in noise.

Method

Twenty-six experienced hearing aid users of 38 to 69 years of age (mean=63.5, SD=6.5) with symmetrical sensorineural hearing loss of 37 to 66 dB HL (mean=49.1, SD=7.0) at 0.5, 1, 2 and 4 kHz were tested. The tasks of the memory recall test, known as the Sentence-final Word Identification and Recall test (SWIR, Ng et al. 2013, 2015) were to 1) repeat the final word after listening to each sentence, and after listening to all 7 sentences, 2) report back, in any order, all final words in a list. Table 1 shows an example sentence list.

All sentences, which were a subset of Swedish HINT sentences, were presented in a 4-talker babble. Presentation levels were individualised to optimise equality in listening effort across participants. Noise level was fixed at 70 dB SPL (C). Speech stimuli were presented at 4.0 dB SNR (SD 2.4) and 1.8 dB SNR (SD 2.2), which correspond to the average SNRs predicting 95% and 70% speech recognition in 4-talker babble respectively. Two signal-processing conditions, OSN OFF and OSN ON, were employed.

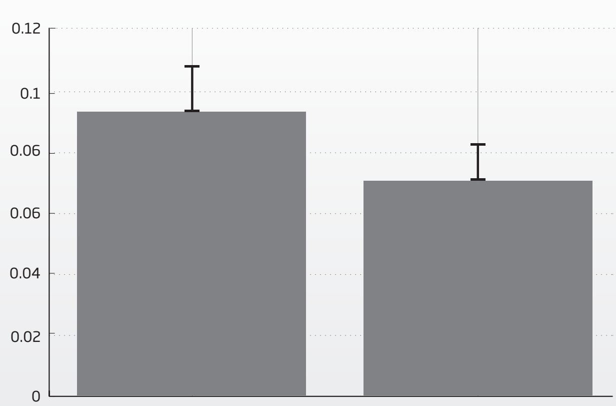

Figure 3: Peak Pupil Dilation averaged across all participants. Error bars show standard errors. REPLACE HA1=Opn, HA2= ALTA2 pro

	List position
"Pappa ska laga min fåtölj"	Primacy
"Tanten handlar en gång i veckan"	
"Rektorn tog fram kastrullen"	Asymptote
"Farmor åker till golfbanan"	
"Golvet täcktes av en vit matta"	
"Frukten packades i sex lådor"	Recency
"Plånboken låg kvar på isen"	

Table 1. An example of Swedish SWIR sentence list. Sentences have a similar grammatical structure. For instance, the first sentence means "Dad must fix my chair".

Listeners were seated in the center of an anechoic room equipped with seven loudspeakers (0°, 45°, 90°, 135°, 225°, 270° and 315°) on a circle with radius of 1 meter. Speech stimuli were presented from the front (0°). Four tracks of one-talker babble were presented from loudspeakers placed at 90°, 135°, 225°and 270°.

Recall performance at the two presentation levels (95%, 70%) in two conditions, OSN OFF and OSN ON, together with the list positions (primacy, asymptote, recency), was analysed. Mean recall performance is shown in figure 4.

Analysis of variance (ANOVA) showed significant main effects of OSN and presentation level, such that better recall was shown for OSN ON, $F(1, 25) = 15.2$, $p < 0.01$, and at 95% speech intelligibility, $F(1, 25) = 11.0$, $p < 0.01$. OSN interacted with both presentation level and list position, $F(2, 50) = 3.3$, $p < 0.05$, indicating that at 95% speech intelligibility, OSN improved recall across all list positions. At 70%, similar results were found and in particular, the improvement was the greatest in primacy list position. This study shows that OSN algorithm frees up cognitive resources and significantly improves memory for speech heard in noise. When the listening situation becomes challenging, OSN further facilitates the encoding of words into long-term memory, which is an ecologically important aspect of speech understanding under adverse conditions.

Speech recognition

Elaine Ng, Linkoping University

This study aimed to compare the benefit of new signal processing in Oticon Opn with the current state-of-the-art technology, Alta2 Pro, using a speech-in-noise test.

Method

This study had the same group of participants as in the memory recall study. Speech recognition thresholds at 50% and 80% intelligibility were obtained using Hagerman sentences (Hagerman & Kinnefors, 1995). Two 10-sentence lists were used for each intelligibility level and technology. The background noise was the speech-shaped noise (SSN) described in Hagerman (1982), which has the same long-term average spectrum as the speech material. The test took place in the same anechoic chamber as in the memory recall study. Speech stimuli were presented at 65 dB SPL (C) from the front (0°). Noise was presented from the remaining 6 loudspeakers.

Results and Analysis

Results are shown in figure 5. An ANOVA revealed a main effect of technology, indicating higher speech-in-noise performance when using Opn than Alta2 Pro, $F(1, 25) = 40.2$, $p < 0.001$, and a main effect of intelligibility level, $F(1, 25) = 552.2$, $p < 0.001$, indicating higher speech-in-noise performance at 80% intelligibility than at 50%.

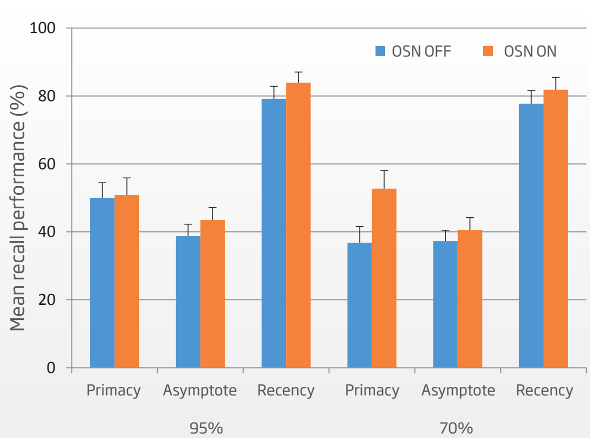

Figure 4. Percentage of correctly recalled words with OSN OFF and OSN ON at 95% and 70% speech intelligibility as a function of list position. Error bars show the standard errors.

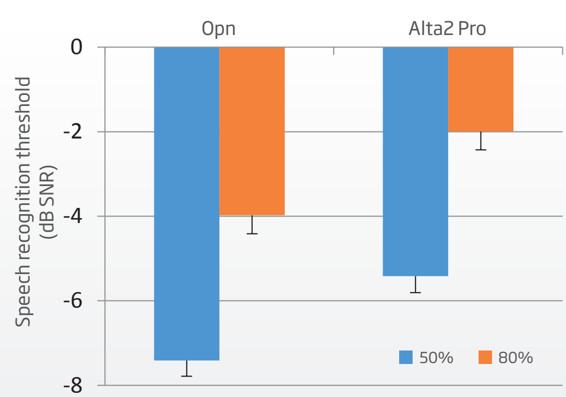

Figure 5. Mean speech recognition thresholds (in dB SNR) at 50% and 80% intelligibility levels using Opn and Alta2 Pro. Error bars show standard errors.

Interpretation

Nicolas Le Goff, Oticon A/S

The studies on the reduction of cognitive effort and the increase in memory recall are world's first (June 2016) - no other study had shown the direct benefit of signal processing in actual hearing-aids using pupillometry or the memory recall test.

The study on cognitive effort shows an average reduction in peak pupil dilation of 26% during the speech-in-noise recognition task when using Opn compared to Alta 2 pro. According to Zekveld et al. 2010, 2011; Koelewijn, 2014, a reduction in peak pupil dilation indicates a reduction in cognitive effort.

The study on memory recall shows an average increase in recall of 25% for recall from long-term memory (primacy, 70% SNR) and 5% for recall from short-term memory (recency, 70% SNR). These results are in line with recall performance obtained with Ng et al. (2013, 2015), in which an offline NR system was used.

The study on speech recognition shows that participants can handle about 2dB more of noise with Opn than with Alta 2 pro, which corresponds to approximately 30% increase in speech understanding performance (Hagerman, 1982).

These results show that the new MSAT technology is a BrainHearing technology. It not only improves speech understanding, but it also reduces the effort demanded to understand speech. The reduction in effort means that cognitive resources are freed up, and can be used for other cognitive tasks, such as remembering conversations.

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