WHITEPAPER
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Oticon Xceed™ Clinical Evidence

SUMMARY

A study at the Örebro University Hospital in Sweden investigated the benefits of in Oticon Xceed and OpenSound Navigator™ (OSN) on speech recognition, listening effort and memory recall in noise for adults with severe-to-profound hearing loss.

By providing more speech information, the use of OSN allowed the listeners to handle more background noise while achieving the same level of speech intelligibility. Subjectively, the listeners perceived significantly less effort while listening to speech in noise with OSN activated. Compared to Oticon Dynamo, the listeners had better recall of words from short-term memory with Oticon Xceed.

These results suggest the BrainHearing™ technology in Oticon Xceed provides better access to speech with less listening effort. This study demonstrates that it is possible to ease cognitive processing of speech for people with severe-to-profound hearing loss.

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Introduction

Having poor speech recognition is one of the most common negative consequences of hearing loss. People with severe-to-profound hearing loss do not only encounter these problems to a more severe degree than people with milder hearing loss. Such degree of hearing loss usually involves hearing difficulties such as broader auditory filter leading to poorer temporal and spectral resolutions, reduced dynamic range, and abnormal loudness growth (see Sockalingam et al., 2011 for review). These problems vary from person to person and can result in complex hearing complaints. Providing optimal hearing aid amplification is crucial but can be much more challenging, for instance they may want more gain than people with lesser degree of hearing loss, yet they are very sensitive to loud sounds once they reach the uncomfortable level. They may not be able to achieve good aided speech understanding even in quiet. Therefore, the benefit of hearing aid technology that a person suffering from severe-to-profound hearing loss can get is dependent on the individual quality of the residual hearing.

In our previous studies, we demonstrated the benefits of the BrainHearing™ technology in Oticon Opn™ and Oticon Opn S™ hearing aids on different levels of speech proceesing for people with mild to moderate hearing loss (Le Goff et al., 2016, Juul Jensen, 2019; Oticon whitepapers; Wendt et al., 2017). These benefits include improved speech recognition, reduced effort during speech recognition and better recall of speech heard in noise. To our knowledge, only few studies looked at these benefits of hearing aid technology for people with severe-to-profound hearing loss. The present study aimed to investigate whether similar benefits using Oticon Xceed and OpenSound Navigator™ (OSN) can be found for this user group.

Methods

Participants

Eighteen participants (average age 45.6 years, range 28 to 70) were included in the analyses. They had symmetrical severe-to-profound sensorineural hearing loss (average PTA 84.0 dB HL, range 70 to >100; see Figure 1) and were regular hearing aid users. They were native speakers of Swedish and had normal or corrected-to-normal eyesight, and none had any eye disease, such as diabetes mellitus, that may influence pupil dilation response. All participants were screened for normal cognitive functioning using the Montreal Cognitive Assessment (MoCA) in Swedish (Borland et al., 2017).

Test setup and conditions

The test setup (Figure 2) was the same for all tests in this study. The participants sat in the middle of a sound booth where target sentences, which were chosen from the Swedish Hearing In Noise Test (HINT; Hällgren et al., 2006), were presented from the front. For all tests administered, a 4-talker babble was used as the background noise, and was fixed at 67 dB A.

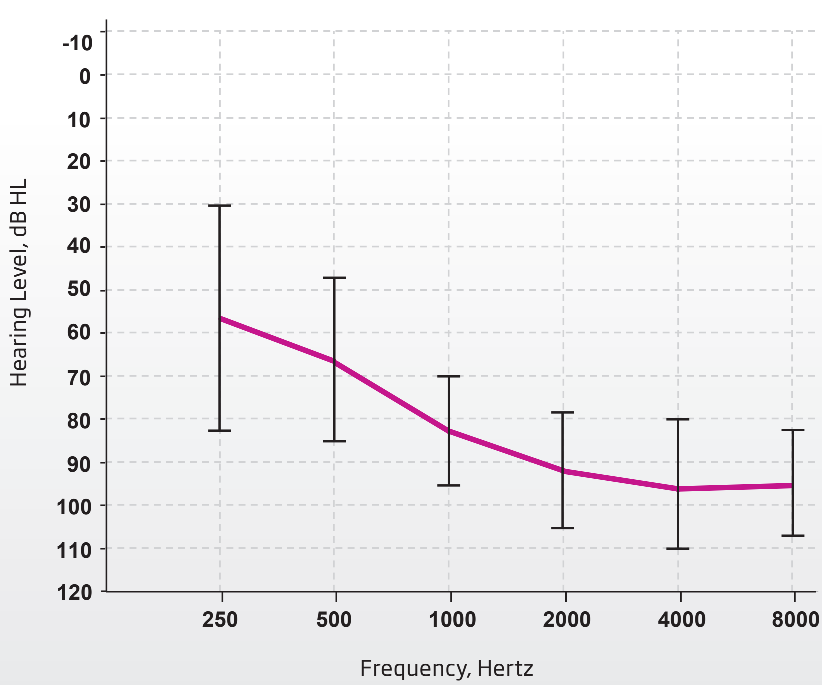

Figure 1. Average pure-tone thresholds across all participants. Error bars indicate standard deviations.

Two test conditions were analysed: OSN ON (high profile) versus OSN OFF in Oticon Xceed™. For the memory recall test, an additional test condition using Oticon Dynamo™ BTE power hearing aids with maximum noise reduction was analysed.

Tests administration

1) Speech recognition

In each test condition, speech recognition threshold (SRT), which is defined as the signal-to-noise ratio (SNR) required to achieve 80% speech intelligibility in noise, was obtained. SNR refers to the difference between the level of the target speech and the level of the background noise. The higher the SNR, the poorer the speech recognition performance. In this test, the presentation level of speech varied based on an adaptive procedure. Given the considerable challenges in understanding speech in noise, speech intelligibility level of 80% was chosen so that the task difiulty would be adquate for people with severe-to-profound hearing loss.

2) Listening effort

Listening effort was measured subjectively and objectively during speech recognition. In this test, the presentation levels of speech and noise were fixed at individualized SNRs, which are equivalent to the SRTs with OSN OFF. For the subjective measure, the participants were asked to rate, on a scale of 1 to 10, the self-perceived effort. For the objective measure, pupil dilation response was recorded during every test condition using a head-mounted eye-tracker developed by Pupil Labs. Pupil dilation response was determined relative to the baseline pupil size (the pupil size while listening to the background noise) as determined for each trial. A smaller pupil size during the task indicates less effort. This method has been used to assess listening effort during speech recognition (for example Wendt et al., 2017; Zekveld et al., 2010).

3) Memory recall

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 last

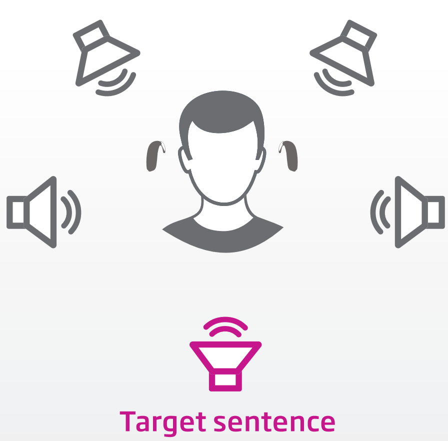

Figure 2. Test set-up of the study. Target sentences are presented from the front. Four-talker babble noise was presented from the four loudspeakers at ±90° and ±135°.

Figure 3. An example test list in the memory recall test.

word after listening to each sentence, and after listening to a list of seven sentences, 2) recall, in any order, as many of the last words in the list as possible. Refer to Figure 3 for an example sentence list. Presentation levels were individualized, which is equivalent to the SRT with OSN OFF obtained in the speech recognition test.

Procedure

The study was conducted in the Örebro University Hospital in Sweden. All participants came in for two sessions. In session 1, pure-tone audiometry was administered. All participants were fitted with a pair of Oticon Xceed1 BTE hearing aids. Two programs, one with OSN ON and one with OSN OFF, were prescribed using the DSE rationale and hearing aid settings were adjusted based on individual preferences. OpenSound Optimizer™ (OSO; Callaway, 2019), which is a feedback prevention technology, was automatically activated. Real ear measurements were performed to ensure sufficient gain was prescribed. The participants had approximately two weeks to get accustomed to the new hearing aids before they came back for session 2. In session 2, tests of speech recognition, listening effort and memory recall were administered. The participants were also asked to compare the hearing aid feedback occurrence and annoyance of Oticon Xceed against their own hearing aids during the two-week field trial. The questions were "Compared to your own hearing aids, how often have you experienced feedback with the trial hearing aids?" and "Compared to your own hearing aids, how annoying was the feedback with the trial hearing aids?".

Results and Discussions

1) Speeh recognition

The overall SRTs (median values) with OSN ON (7.9 dB SNR) was significantly better than that with OSN OFF (9.4 dB SNR), $t(17) = 0.19$, $p < 0.01$.

When we took a closer look at the individual data, there was a large variation of speech recognition performance (see Figure 4), which is not uncommon in this user group. The SRTs averaged across both test conditions ranged approximately from +2 to +22 dB SNR. Some participants needed advantageous SNRs (+20 dB SNR or above) where the speech level was much higher than the background noise level in order to achieve 80% speech intelligibility. This observation could be related to the quality of their residual hearing, despite of having the same degree of hearing loss.

The implication of such a large individual variation is that the benefit from OSN could vary greatly. Figure 5 illustrates the benefit of OSN in terms of the availability of speech information estimated using the Speech Intelligibility Index (SII) over a range of SNRs. SII is commonly used to predict aided speech recognition performance (refer to Hornsby, 2004 for a comprehensive overview of SII). The SIIs shown in Figure 5, which are

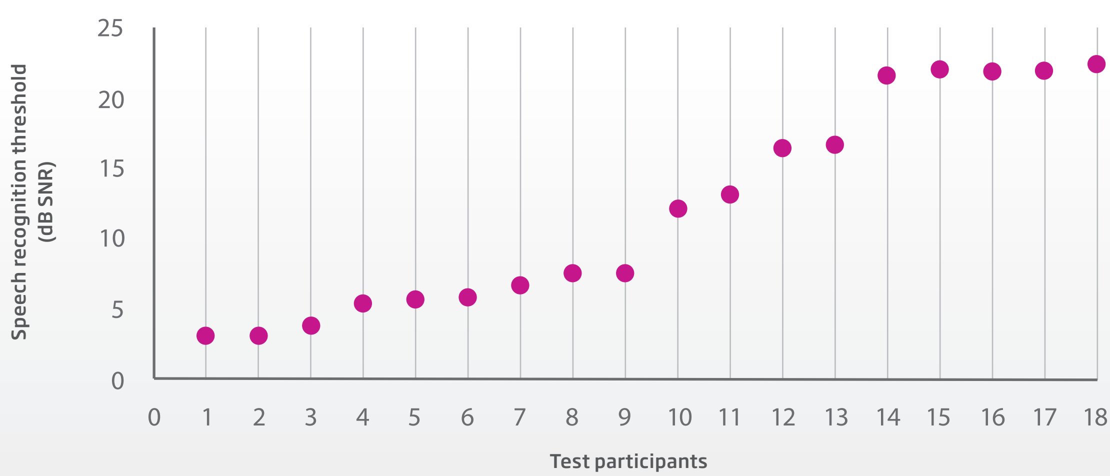

Figure 4. Individual speech recognition thresholds with both test conditions combined.

estimated based on similar technical measurements described in Ng & Rumley (2019, Oticon Whitepaper), illustrate how much more speech information OSN ON can provide compared to OSN OFF at different SNRs specifically in the background noise used in this study and for listeners with severe-to-profound hearing loss. OSN is designed to enhance speech in noise and its effect varies depending on the complexity of the listening environment (Le Goff et al., 2016, Oticon whitepaper). As SNR increases, the improvement in SII delivered by OSN decreases. In the background noise used in this study, the noise removal system in OSN has a minimal effect when SNR is 15 dB or above (see Figure 5). This could mean that the participants who needed high SNRs to achieve 80% speech intelligibility would have rather limited benefit from OSN.

To further investigate the benefit of OSN in environments where the noise removal system in OSN is activated, we performed a subanalysis of the results from the participants whose SRT with OSN ON was 15 dB SNR or below. Eleven participants were included. Statistical analysis showed that the overall SRT was significantly lower when OSN was activated, $t(10) = 3.5$, $p < 0.01$ (see Figure 6), which was also found in the analysis which included all participants. The results suggested that with OSN OFF, the speech needed to be almost 2 dB louder in noise in order to achieve 80% speech intelligibility as with OSN ON. In other words, OSN allows listeners to handle more noise.

Then, for each participant, we estimated two SII values based on the SRTs obtained when OSN ON and OSN OFF, respectively. The average SII with OSN OFF across all participants was approximately 57% whereas the average SII with OSN ON was approximately 68%.

To summarize, OSN cleans up the speech signal in noise by improving the SNR and provides more speech information as shown in the SII estimations. The results showed that OSN significantly improved SRT, suggesting that the participants could handle 2 dB more background noise to achieve the same level of speech intelligibility when OSN was activated. Based on the SII estimations, the significant improvement in SRT with OSN activated corresponds to up to 10% more speech information. The results also suggest a large variation in SRT which possibly affects how much one could benefit from OSN.

2) Listening effort

Subjective measure. Results are shown in Figure 7. Statistical analysis indicated that the subjective effort rating was lower for OSN ON as compared to OSN OFF,

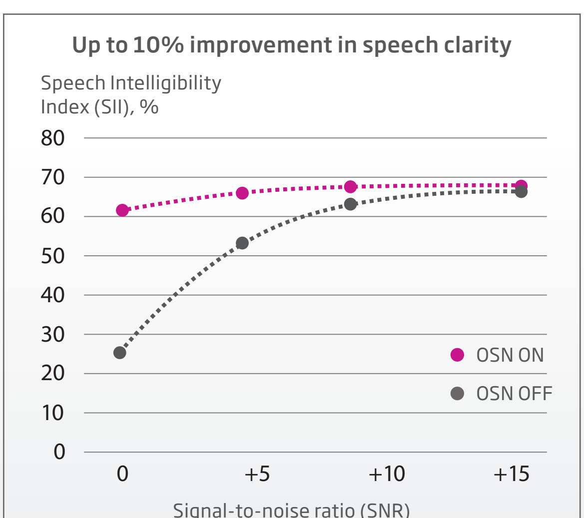

Figure 5. Estimated speech Intelligibility Index (SII) as a function of SNR with OSN ON and OSN OFF.

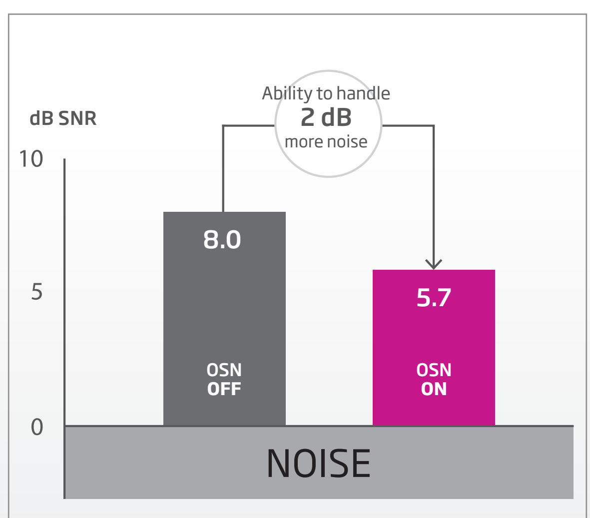

Figure 6. Results of the speech recognition test. The number on each bar represents the average SRTs (in dB SNR) across participants in the corresponding test condition in the subanalysis (n=11).

$F(1, 10) = 3.4, p < 0.01$. This corresponds to up to 10% less percevied listening effort with OSN.

Objective measure. Pupil response was measured for each of the participants. Preliminary analysis showed that the mean pupil dilation across participants was smaller with OSN ON (0.037 mm) as compared to OSN OFF (0.053 mm). Even though the objective results showed a similar trend (reduced pupil dilation with the use of OSN) as in our previous studies, the difference between OSN ON and OSN OFF did not reach statistical significance ($p > 0.05$). This is probably related to the wide spread of speech recognition performance and also the limited benefit from OSN for some participants. Further analyses are warranted to better understand the relationship between pupil response, speech recognition and listening effort.

3) Memory recall

In the memory recall test, how well one could remember the target speech is partly dependent on the audibility of the target speech. The speech recognition test revealed that some participants had SRTs of +15 dB SNR or above, where noise level is relatively low compared to the speech level. This could be an indication that achieving good aided audibility and speech intelligibility remains challenging for these people. Oticon Xceed is equipped with technology designed for optimal audibility with consistent amplification (OSO) and enhancement of speech in noise (OSN). In order to show the maximum contrast that Oticon Xceed can bring, an additional test condition was analyzed. Recall performance using Oticon Xceed with OSN ON was compared to that using Dynamo with maximum noise reduction. As in the previous tests, the effect of OSN (ON versus OFF) was also examined.

Memory recall from long-term memory (sentences 1 and 2) and short-term memory (sentences 6 and 7) was analysed. When comparing OSN ON and OSN OFF in Oticon Xceed, there was no significant difference in recall performance from neither long- nor short-term memory. When comparing Oticon Xceed with OSN ON against Dynamo with maximum noise reduction, short-term memory recall was significantly better, $F(3, 147) = 19.4, p = 0.00$ (Figure 8). This corresponds to up to 15% better short-term memory recall. Better recall from short-term memory is believed to be associated with more rapid speech perception and easier encoding of heard speech into working memory for further processing (Ng et al., 2013), which could be related to clearer perceptual representations of the target speech with Oticon Xceed. The results did not show any significant difference in recall performance from long-term memory between Oticon Xceed and Dynamo.

After the two-week trial of Oticon Xceed, the participants rated the feedback occurrence and annoyance

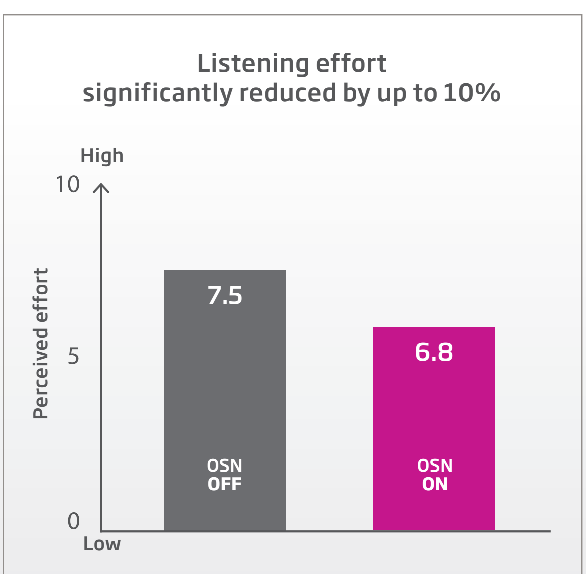

Figure 7. Results of the subjective measure of listening effort (n=18). The number on each bar represents the average perceived listening effort in the corresponding test condition.

on a 5-point scale ranging from much less often/annoying (-50), somewhat less often/annoying (-25), no difference (0), somewhat more often/annoying (25) and much more often/annoying (50). Overall, they reported less feedback occurrence and annoyance (average ratings were -14.7 and -6.5 respectively) with Oticon Xceed when compared with their own hearing aids.

Interpretations and Implications

The speech recognition test showed significantly better speech-in-noise performance with OSN by allowing listeners to handle relatively more noise. Based on the results, SIIs were calculated to show that OSN provides additional speech information over a range of SNRs and presumably clearer representations of speech signal in noise. Furthermore, OSN reduces listening effort as perceived by the listeners. When compared to Dynamo, performance using Oticon Xceed resulted in better recall from short-term memory, suggesting that speech could be perceived and transferred to working memory, the mental workbench, more easily and efficiently, which allows better recall of speech that is just being heard.

For people suffering from hearing loss, speech processing has found to be more effortful and may also lead to fatigue (e.g. Alhanbali et al., 2017; Hornsby & Kipp, 2016). Because of the severity of the hearing loss and the quality of the residual hearing, listening is still often challenging for people with severe-to-profound hearing loss. They often need to listen attentively and use other cues such as reading lips and prior contextual and linguistic knowledge to complement the speech input. All these aspects make listening effortful. Our previous studies showed listening effort can be reduced with the use of OSN in the Oticon Opn and Opn S hearing aids (Le Goff et al., 2016, Juul Jensen, 2019; Oticon whitepapers; Wendt et al., 2017). The present study extends this finding to people with severe-to-profound hearing loss using Oticon Xceed, which is demonostrated to provide better access to speech and invoke less effort during speech perception. This finding is further suppored by the improved recall from short-term memory, which indicates facilitation of cognitive processing of speech.

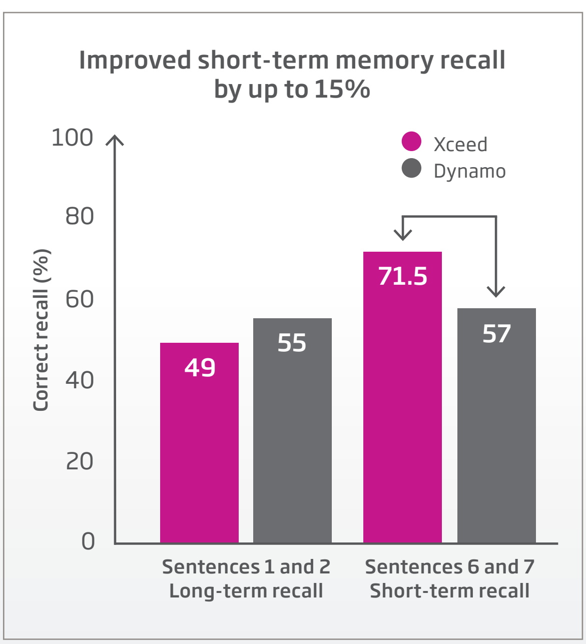

Figure 8. Results of the memory recall test showing recall performance (in percent) from long- and short-term memory in each condition (n=18).

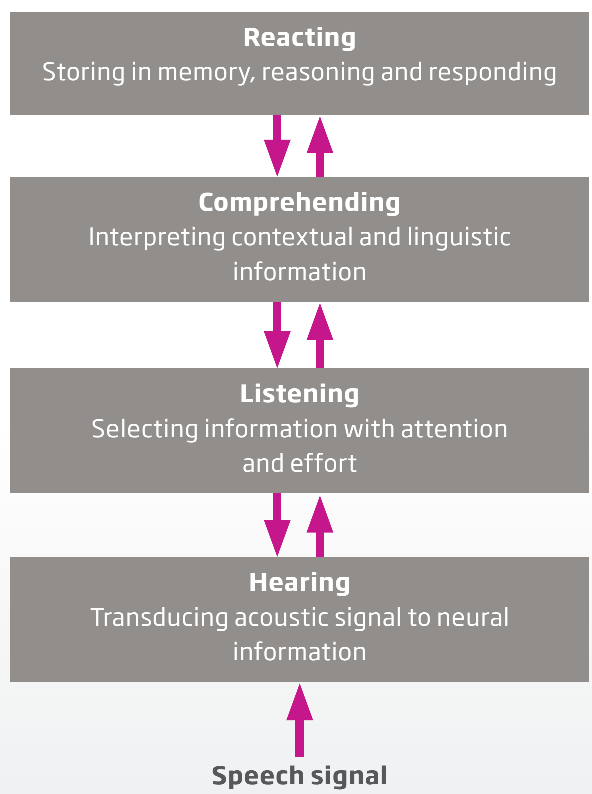

Figure 9. A conceptual model showing different levels of processing of speech input (adapted from Stenfelt & Rönnberg, 2009).

Speech processing is comprised of a series of complex mental processes and is particularly problematic in noise and for people with hearing loss. The clinical study presented in this whitepaper, together with our previous clinical evidence, has consistently shown how the BrainHearing benefits of the new technology in the Oticon hearing aids for different user groups. The BrainHearing benefits concerning speech recognition, listening effort and memory are highly relevant aspects in speech processing, as illustrated in Figure 9. By delivering optimal speech signal, different levels of speech processing could be facilitated and made easier, and hence providing upstream benefits such as reduced listening effort and better memory recall for people with hearing loss.

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References

1. Alhanbali, S., Dawes, P., Lloyd, S., & Munro, K. J. (2017). Self-reported listening-related effort and fatigue in hearing-impaired adults. Ear and Hearing, 38(1), e39-e48.
2. Borland, E., Nägga, K., Nilsson, P. M., Minthon, L., Nilsson, E. D., & Palmqvist, S. (2017). The montreal cognitive assessment: normative data from a large swedish population-based cohort. Journal of Alzheimer's Disease, 59(3), 893-901.
3. Callaway, S. L. (2019). Introduction to OpenSound Optimizer. Oticon White Paper.
4. Hornsby, B. W. (2004). The Speech Intelligibility Index: What is it and what's it good for?. The Hearing Journal, 57(10), 10-17.
5. Hornsby, B. W., & Kipp, A. M. (2016). Subjective ratings of fatigue and vigor in adults with hearing loss are driven by perceived hearing difficulties not degree of hearing loss. Ear and Hearing, 37(1), e1-e10.
6. Hällgren, M., Larsby, B., & Arlinger, S. (2006). A Swedish version of the Hearing In Noise Test (HINT) for measurement of speech recognition: Una versión sueca de la Prueba de Audición en Ruido (HINT) para evaluar el reconocimiento del lenguaje. International Journal of Audiology, 45(4), 227-237.
7. Juul Jensen, J. (2019). Oticon Opn S Clinical Evidence. Oticon Whitepaper.
8. Le Goff, N., Wendt, D., Lunner, T., & Ng, E. (2016). Opn Clinical Evidence. Oticon Whitepaper.
9. Ng, E. H. N., Rudner, M., Lunner, T., Pedersen, M. S., & Rönnberg, J. (2013). Effects of noise and working memory capacity on memory processing of speech for hearing-aid users. International Journal of Audiology, 52(7), 433-441.
10. Ng, E. H. N., Rudner, M., Lunner, T., & Rönnberg, J. (2015). Noise reduction improves memory for target language speech in competing native but not foreign language speech. Ear and Hearing, 36(1), 82-91.
11. Ng, E. & Rumley, J. (2019). The Audiology of Oticon Xceed and Oticon Xceed Play. Oticon Whitepaper.
12. Sockalingam, R., Lundh, P., & Schum, D. J. (2011). Severe to profound hearing loss: What do we know and how do we manage it? Hearing Review, 18(1), 30-33.
13. Stenfelt, S., & Rönnberg, J. (2009). The signal cognition interface: Interactions between degraded auditory signals and cognitive processes. Scandinavian Journal of Psychology, 50(5), 385-393.
14. Wendt, D., Hietkamp, R. K., & Lunner, T. (2017). Impact of noise and noise reduction on processing effort: A pupillometry study. Ear and Hearing, 38(6), 690-700.
15. Zekveld, A. A., Kramer, S. E., & Festen, J. M. (2010). Pupil response as an indication of effortful listening: The influence of sentence intelligibility. Ear and Hearing, 31(4), 480-490.

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