WHITEPAPER
2019

Oticon Opn S Clinical Evidence

INTRODUCTION

This whitepaper presents a summary of the clinical research studies investigating the client benefits of the key features introduced in Opn S, namely the OpenSound Optimizer™ and new automatics in the OpenSound Navigator, namely the OSN Booster. Clients can expect benefits such as increased speech understanding, less cognitive effort when listening, and enhanced memory recall. The new and stronger platform, Velox S, allows for the OpenSound Optimizer to detect and prevent audible feedback pro-actively, even before it occurs. This new feature enables clinicians to open up clients' worlds with an additional six decibels of gain in more open fittings than before, without the risk of feedback* (see white paper Introduction to OpenSound Optimizer, Callaway 2019, for more details). Thanks to this new OpenSound Optimizer and the Booster in OpenSound Navigator, Opn S now delivers the OpenSound experience to even more users.

Speech recognition is one of the key measures of hearing aid performance, and it was naturally part of the investigations into the performance of Opn S. Testing speech recognition gives a good indication of whether audibility is properly restored and speech cues sufficiently preserved, but it does not take into account the complex cognitive processes that occur in the brain when making sense of speech in noise, nor the full benefits of signal processing (e.g., Keidser, 2016). Therefore, cognitive measures were also included, while investigating the advanced BrainHearing™ benefits in Opn S.

*For prescribed fittings according to best practice

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Fitting to target: a current clinical challenge

Working with currently available devices, clinicians often run into a fitting compromise. The clinician wishes to provide optimal gain with good sound quality in an open fitting without feedback, but the reality is much more complex. Feedback management systems are a necessity in hearing aids, but they can negatively affect sound quality (Waterschoot, 2009; Guo, Jensen & Jensen, 2013) and impose reduced gain in order to combat feedback, as well as introducing distortion into the speech signal in the form of large frequency shifts or other feedback-related artefacts. Besides feedback management strategies, there are other reasons why many end-users are not getting the amount of gain they are prescribed. Research shows that up to 70% of fittings are more than 10 dB below the target between 1 and 4 kHz in fittings where the first fit approach is used (Sanders et al, 2015; Munro et al, 2016; Valente et al, 2018).

In the first fit approach, as opposed to using best practice, the target is not verified with real ear measurements; however, a benefit is that a first fit approach saves time in the clinic and can be used for both generic and proprietary rationales. While there are many good reasons why clinicians choose the first fit approach, it may have some drawbacks that are not necessarily obvious. Research shows that even in mild hearing losses, the brain can undergo changes early on due to (untreated) hearing loss (Campbell & Sharma, 2013). It is possible that these changes are not prevented satisfactorily if end-users are severely underfitted. Fortunately, for Opn S, the first fit accuracy is improved from 62% to 84%, prior to any fine-tuning (Callaway, 2019). Nevertheless, even clinicians who use the best practice of real ear measurements for verification are often met with the challenge that the hearing aid(s) cannot meet target without compromising on feedback occurrence and open acoustics (i.e. occlusion). With the OpenSound Optimizer, this challenge is minimised by giving access to 6 dB more gain combined with pro-active feedback prevention.

Noisy environments: a continuing end-user challenge

Other challenges also exist that are related more to the daily life of hearing aid clients. Listening with a hearing loss is effortful and requires more cognitive resources (Pichora-Fuller, 2016). While strong evidence shows that the OpenSound Navigator significantly reduces this issue (see e.g. Opn Clinical Evidence 2016, Oticon whitepaper), there is still room for improvement. With the new automatics of the Booster in the OpenSound Navigator, the OpenSound Navigator can give even more help by adding the option of a Very High transition in the OpenAutomatic, and adding 3 dB of noise reduction in simpler environments. Clients are also given the possibility to activate the Booster whenever they feel the need, making listening even easier on the brain than before.

Building on the strong evidence package from Oticon Opn, two studies were conducted on speech understanding, cognitive load, and memory recall. The studies assessed the additional BrainHearing benefits with Oticon Opn S, focusing on the abovementioned features and their benefits in relation to the issues presented. This whitepaper is divided into three main sections: speech understanding, listening effort, and memory recall, with the results of the two studies presented in the context of these three outcomes.

Table 1 Overview of the experimental conditions

OpenSound Optimizer		Booster	
Oticon Opn 1	Oticon Opn S	Oticon Opn with OSN Medium	Oticon Opn S with OSN Booster
Underfit (not target matched) on NAL-NL2	Target matched on NAL-NL2	First fit approach, VAC+	First fit approach, VAC+
55 dB Masking noise → simpler; soft gain		67 dB Masking noise → noisy, complex; moderate gain	

The experimental conditions

Table 1 shows an overview of the experimental conditions. The benefit to speech understanding and cognitive effort in listening was tested by comparing 1) Opn S with OpenSound Optimizer to Opn with traditional feedback management, and 2) Opn S with OpenSound Booster to Opn with OpenSound Navigator in Medium transition.

For OpenSound Optimizer, the hearing aids were target matched to the NAL-NL2 rationale, allowing a 2-dB deviation acceptance, and verified using the Audioscan Verifit1. The Opn devices were simulated as underfit with 6 dB below the target from 2-4 kHz. Underfitting by 6 dB was the chosen parameter for several reasons: an internal competitor analysis from 2017 showed that some manufacturers limit the gain and therefore cannot reach target, while others can target-match. The discrepancy between these devices was 6 dB in the 2-4 kHz area. This area is important for speech, but is often feedback prone, which can necessitate gain limitation. Another reason was that the target match deviance acceptance criteria according to best practice is 5 dB (British Society of Audiology, 2018; Bagatto et al, 2011). Thus, it is assumed that many end-users currently use devices that are underfit in an important speech area, and if one should simulate this, it needs to be more than 5 dB below target.

The OpenSound Optimizer was tested with an average of 55 dB SPL masker level, to provoke soft level gain in the devices, as soft gain stresses feedback systems the most. The Booster was tested with 67 dB SPL masker level, creating a more complex and noisier situation, simulating where end-users typically need more help. The signal-to-noise ratios (SNRs) were adjusted individually to correspond to either 50%, 77%, or 80% speech recognition. These conditions were the foundation of the two experiments investigating Opn S: one in Denmark under collaboration with the Eriksholm Research Centre, and one in the Oldenburg Hörzentrum in Germany. 18 and 19 hearing-impaired listeners with a mix of sensorineural hearing losses ranging from mild-to-moderate to ski slopes were tested at each site respectively, a total of 37 participants. Figures 1 and 2 show the average audiograms of the two types of hearing losses.

Speech understanding

To investigate speech understanding improvements in Opn S, the Danish study used the Danish Hearing in Noise Test (HINT, Nielsen & Dau, 2011) for speech recognition testing, while the German study used the Oldenburg sentence test (Oldenburger Satztest, OLSA). In both methods, sentences are presented in noise, and listeners are asked to repeat back what they heard when the noise terminates. By testing this in several conditions, it is possible to explore speech understanding improvements from Opn to Opn S.

Results

Both the Danish and the German studies showed an increase in speech understanding for Opn S. Figure 3 shows the results for the OpenSound Optimizer in the

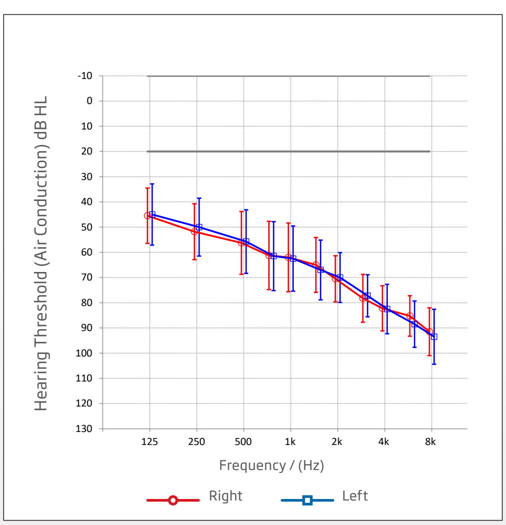


Figure 1. Average audiogram with standard deviations for German participants

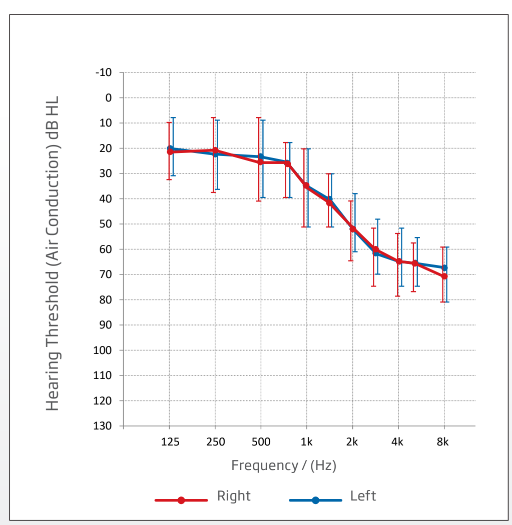


Figure 2. Average audiogram with standard deviations for Danish participants

two intelligibility levels for the German participants, with an average significant improvement of 1.2 dB SNR. Figure 4 shows the results for the Opn S Booster, where a significant average SNR improvement of 1.6 dB was found. Similar results were found for the Danish participants, with an average improvement of 12 percentage points (not shown here). In the Danish study, the SNR had to be kept constant as this is a condition for the pupillometry method (see next section). Therefore, results from the Danish study are described in percentage points, whereas the German study looked at SNR improvements. For Opn S, results show that the new processing optimises an already excellent speech understanding, adding those extra missed words that give the full sentence recognition.

Cognitive effort in listening

To investigate cognitive effort in listening, two different methods were applied at the two research sites. Pupillometry is the method of continuously recording a test person's pupil dilation while performing another task, such as listening to speech in noise. Pupillometry is an excellent method for investigating objective listening effort and has been used extensively already within hearing research (e.g. Wendt et al, 2017; Ohlenforst et al, 2018). When doing something demanding – such as listening to speech in noise – an increase in effort is reflected by dilation in the pupil (Beaty, 1982). Studies have used the peak pupil dilation (PPD) as the main outcome measure for maximum effort (e.g. Ohlenforst et al, 2018, Wendt et al, 2017, Zekveld et al. 2011). However other studies show there are even more sensitive ways of analysing pupil dilation (Mirman et al, 2008, Wendt et al, 2018, Juul Jensen et al, 2018). Growth Curve Analysis (GCA) examines how the pupil changes over time, and can therefore analyse for example how effortful it was to recognise the speech, and how effortful it was to retain it in your memory before you respond to the task, enabling a much more precise interpretation of the cognitive load. In the Danish study, the GCA was applied to the data.

In the German study, the Adaptive Categorical Listening Effort Scaling (ACALES) (Krueger et al, 2017) was used for investigating perceived, subjective listening effort. In this method, listeners rate their perceived effort listening to speech in noise on a 13-category scale, ranging from no effort to extreme effort, with an added category of only noise when listeners no longer detect any speech signal at all. In this way, an Effort Scaling Unit (ESCU) can be obtained, which corresponds to a category of a certain amount of effort (e.g., 7 ESCU = moderate effort). By having data from both objective and subjective effort measurement methods, it is possible to get a fuller picture of the Opn S listening experience.

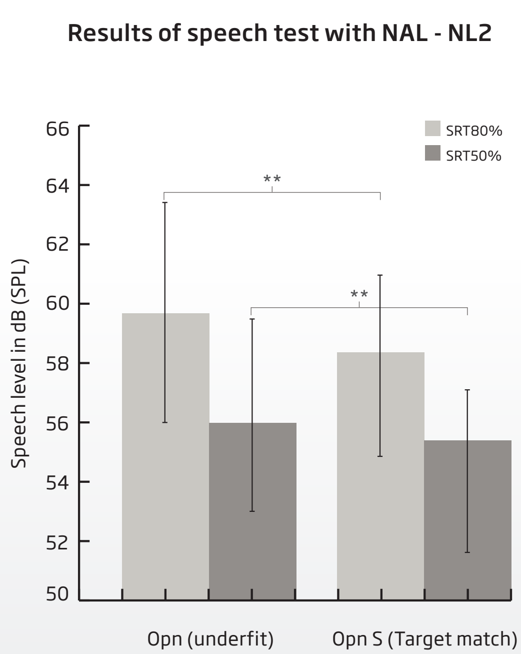


*Figure 3. Speech understanding results for OpenSound Optimizer in Opn S from German participants, showing an average improvement of 1.2 dB SNR, corresponding to an approximately 15% increase in speech intelligibility. ** $p < 0.001$*

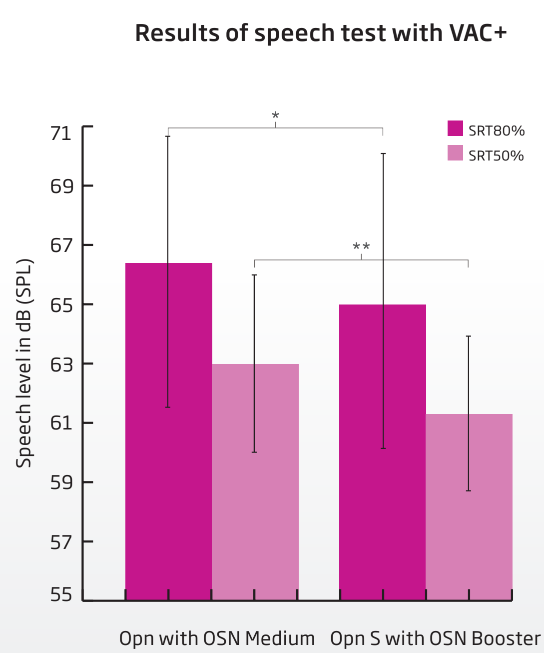


*Figure 4. Speech understanding results for OSN Booster in Opn S from German participants, showing an average improvement of 1.6 dB SNR, corresponding to an approximately 15% increase in speech intelligibility. * $p < 0.05$; ** $p < 0.001$*

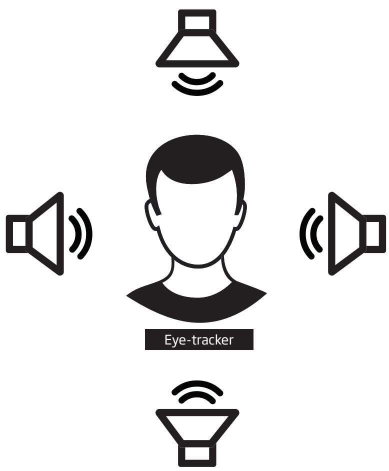


Figure 5. Spatial setup for the two studies, with target speech at 0°, male talkers from +/- 90°, and steady state noise from -180°. The eye-tracking camera was only applicable in the Danish study.

Figure 5 shows the spatial setup of the two experiments (the eye tracker was only applicable at the Danish site). Speech was presented from the front, and a male talker was presented from each side to create interfering speech signals, while steady state noise was presented from behind.

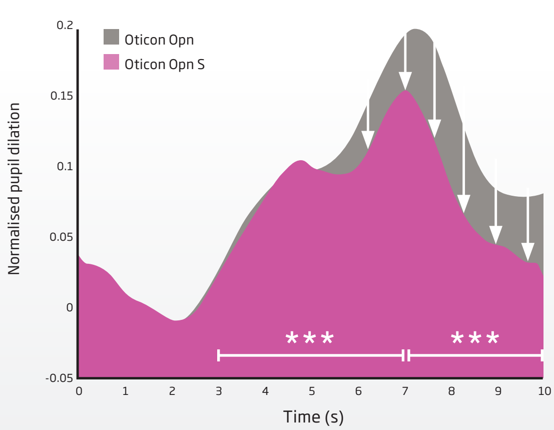
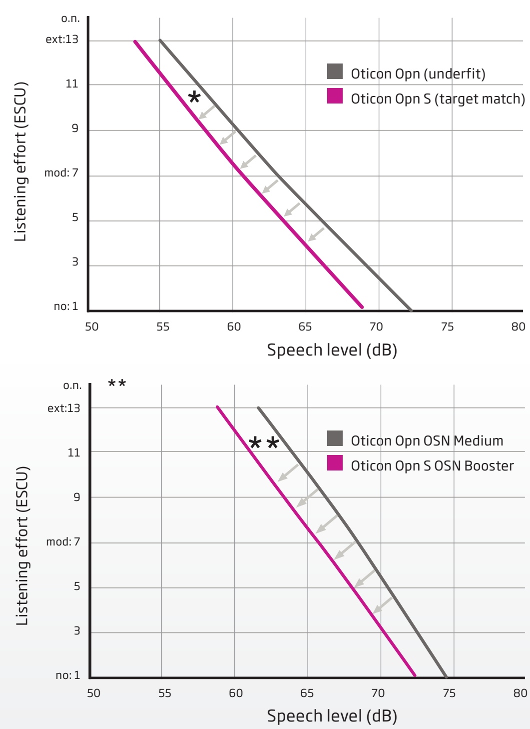


Figure 6. Pupil dilations across time, showing a significantly smaller "Area under the curve" for Opn S. Dilations are significantly smaller during speech processing (3-7 seconds) (p < 0.000) and for retaining the information in memory (7-10 seconds) (p < 0.000).

Results

The results depicted in figure 6 show a decreased pupil dilation for recognising speech and for retaining it in your memory, indicating reduced listening effort for Opn S. What should be noted is the "area under the curve", which is the general pupil dilation across time. When this area is smaller, the effort as assessed from global cognitive load via pupillometry was smaller as well. For Opn S, a reduction of up to 45% was seen for listening to the speech and retaining information in memory, translating to significantly less cognitive effort ($p < 0.000$).

For subjective listening effort, results also showed a significant reduction. Figure 7a shows the speech level presented at 55 dB, meaning a speech level of 65 had an SNR of 10 dB. For figure 7b, noise was presented at 67 dB, such that a speech level of 65 had an SNR of -2 dB. In the ACALES method, the further the line is to the left, the less perceived effort. By comparing the pink and grey lines, it is possible to estimate the difference in effort for different speech levels. Opn S showed an average reduction of 10% perceived listening effort, indicating that the experience of listening with Opn S is much less effortful for the brain than with Opn.



*Figures 7a (above) and b (below). Opn Underfit (17.1) grey line, and Opn S Target match (19.1), pink line. The more on the left the curve is, the less effort. * p<0.05, ** p < 0.001*

Together, the results related to reducing cognitive load showed significantly reduced listening effort on both subjective and objective data. In other words, Opn S facilitates easier communication for the brain, and this frees up resources for other cognitive tasks.

Memory recall in listening

Research shows that if people with hearing loss are to do well in difficult listening situations such as understanding speech in noise, they are required to use other cognitive resources, like working memory (Rudner, Rönnberg, & Lunner, 2013). According to the Ease of Language Understanding model (ELU model, Rönnberg, 2003; Rönnberg et al, 2008; Rönnberg et al, 2013), because working memory resources are not unlimited, if working memory is used for making sense of speech, it is not available for ensuring later memory recall of what was heard. Furthermore, these resources are not unlimited, and when the user constantly has to use extra resources to understand speech, it can be exhausting and have long-term effects, such as fatigue and social isolation (Hornsby, 2016). Fortunately, new technology such as the OpenSound Navigator can improve memory recall (see Opn Clinical Evidence whitepaper, 2016).

To investigate further memory recall benefits of the Opn S compared to Opn, the same participants were tested in the conditions described above, using a listening span measurement in Oldenburg. In this listening span test, blocks of 4 or 6 sentences are presented to the listener at high SNRs (speech intelligibility around 95%), and the listener is asked to repeat each sentence and remember the final word. When the block is finished, the listener must recall as many words as possible. The list positions were also analysed, where words that were presented in the beginning of the block are called 'primacy', and those presented at the end are called 'recency'.

Results

An analysis of variance (ANOVA) showed a significant interaction with list position, $F(1, 18) = 4.9$, $p < 0.05$. The results (shown in figure 8) indicate that on recency, Opn and Opn S are the same, but for the primacy list position, Opn S was significantly better, meaning Opn S helps save words in long-term memory to a greater extent than Opn. As explained in previous white papers, this is an ecologically important aspect of speech understanding (Le Goff, 2016).

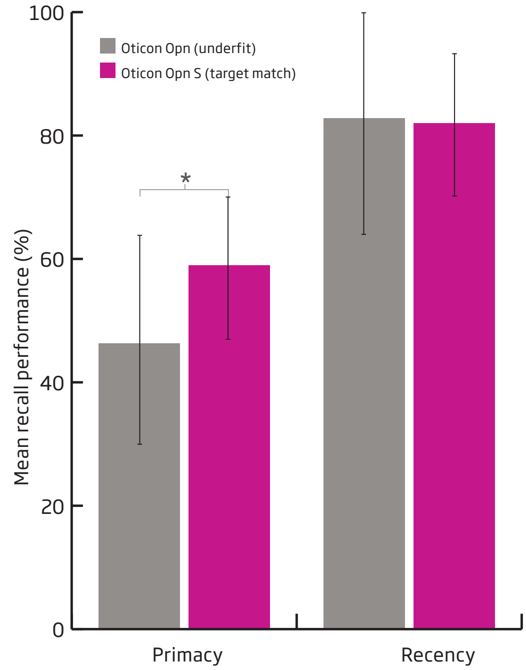


Figure 8. Mean recall performance in percent, showing a significant effect of the Opn S on primacy
** $p < 0.05$*

With an increased memory recall, clients can expect to have more mental resources available for other things than just understanding speech in noise. This could be remembering conversations and staying active in social situations for longer (see also white paper Closing a gap to normal hearing, Juul Jensen, 2018).

Summary & Clinical Interpretation

The studies on further improvements in speech understanding, further reductions in cognitive effort, and even more improved memory recall, build on the discoveries of these benefits from studies on the Oticon Opn hearing aids in 2016. With Oticon Opn S, these BrainHearing benefits are taken to the next level thanks to the OpenSound Optimizer and the improved power of the Velox S platform, driving the updated OpenSound Navigator.

The studies on cognitive effort in listening show an average reduction around 40% on the pupil dilation during listening, showing a significant reduction both for the time when participants simply recognised the speech, and also when having to retain the information in memory before responding. This objective result shows how the global cognitive load for listening is reduced with Opn S. Furthermore, the perceived listening effort was reduced with an average of 10%, showing a strong full picture of easier communication for the brain with both objective and subjective results on cognitive effort.

The study on memory recall shows an average increase in recall of 12 percentage points for Opn S with the OpenSound Optimizer, building on top of the already 20% increase in recall from the Opn legacy. These results were significant for primacy, showing how the new features in Opn S facilitate long-term memory.

The studies on speech understanding show that participants improved with an average of 15% percent, where the participants could handle an average of 1.5 dB more noise with the Opn S compared to the Opn. Using the psychometric function of speech testing in noise (Wagener, Brand, & Kollmeier, 1999), this translates to an increase in speech intelligibility around 15%. This is building on an already great speech understanding in Opn, giving clients even better speech understanding with Opn S.

These results show that the enhanced power of the Velox S platform that is enabling OpenSound Optimizer and new automatics in the OpenSound Navigator underlines the BrainHearing benefits in Oticon Opn S. Together with the Booster, the OpenSound Optimizer facilitates BrainHearing benefits with more fitting flexibility, more open fittings, better prescribed target match, more access to speech cues, and more headroom for dynamic listening environments, while making it easier for the clinician to satisfy clients (Callaway, 2019). This whitepaper described how these technological innovations bring new BrainHearing benefits, resulting in users getting better speech understanding while enjoying a reduced cognitive effort. With less effort needed for understanding speech, Opn S facilitates easier communication for the brain, liberating cognitive resources that are made available for other important things, such as remembering more.

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