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Improving comfort and speech clarity in wind

Oticon Real™, new competitive benchmark

ABSTRACT

Wind noise is an unwanted sound that poses significant problems for hearing aids users. It causes discomfort and reduces speech clarity. On windy days, some users may choose to avoid wearing their hearing aids during outdoor activities and thus miss out on environmental sounds and the opportunity to participate in conversations. With Oticon Real, we introduced the Wind & Handling Stabilizer (WHS), a new wind noise management system that is proven to eliminate wind noise more effectively than in the previous generation of Oticon products. WHS yields clinical benefits both in terms of subjective wind noise loudness and speech clarity, as reported by hearing aid users. This new competitive benchmark adds further evidence to the effectiveness of WHS.

Through a systematic technical study, we examined how Oticon Real 1 performed in windy conditions in comparison to hearing aids from three top competitors each with their wind noise management systems set to the maximum activation setting. The evaluation targeted two key factors that illustrate the greatest impacts of wind noise on the subjective experiences of hearing aid users: listening comfort and speech clarity. We recorded wind alone and speech in wind for all hearing aids fitted on a head-and-torso simulator. Lower wind noise levels and lower predicted loudness were obtained for Oticon Real compared to all three competitors. In addition, Oticon Real provided the largest contrast between speech and wind noise and gave access to more speech cues than the three tested competitors. These results clearly strengthen the findings of the earlier subjective investigation, with Oticon Real providing more listening comfort and clearer speech in windy situations.

EDITORS OF ISSUE

Valentina Zapata-Rodríguez, Hella Flocken and Sébastien Santurette
Centre for Applied Audiology Research, Oticon A/S

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Oticon Real™ and the new Wind & Handling Stabilizer

Wind noise can be a significant challenge for hearing aid users, often causing discomfort and frustration. Whether you are outdoors on a breezy day, cycling along a trail, or attending an open-air gathering, wind noise can interfere with speech clarity and limit your listening experience. This noise is generated by the turbulence of air flowing around the hearing aid microphones. It is an undesirable and intrusive sound that can reach high and uncomfortable levels, even in mild wind conditions (Zakis, 2011). Hearing aid users often find wind noise to be annoying, unpleasant, or irritating, particularly when walking outside with a friend (Gade et al., 2023). Wind noise can then be an obstacle for users who enjoy outdoor activities, especially when wind is present.

Oticon's latest innovation to remove wind noise, Wind & Handling Stabilizer (WHS), is the new addition to MoreSound Intelligence™ 2.0 (MSI 2.0). This system is designed to effectively minimize the wind and handling noise entering the sound processor and to suppress any residual noise rapidly. As a result, the audibility of other pertinent sounds is optimized, and contributes to an overall enhanced listening experience in windy conditions. WHS uses microphone analysis and artefact prevention technology to constantly monitor noise correlation between the two hearing-aid microphones and prioritize the microphone with least wind noise only in affected frequency channels. WHS monitors wind 500 times per second and works in 24 frequency channels up to 10 kHz in Oticon Real 1. This contrasts with earlier generations of wind management systems that acted mainly below 1.5 kHz and thus increased the burden on noise reduction systems, often requiring overall gain reduction as a last-resort strategy. Thanks to RealSound Technology™, Wind & Handling Stabilizer is further optimized to work together with multi-speaker access technology and deep-neural-network based noise suppression, which leads to large improvements in wind noise removal over the whole frequency range (Gade et al., 2023).

A recent technical and clinical study (Gade et al., 2023) in one of the world's largest university-owned wind tunnels, the Poul la Cour Tunnel at the Technical University of Denmark (PLCT, 2022), showed that Oticon Real 1 with Wind & Handling Stabilizer reduced wind noise more effectively and allowed more access to speech details than Oticon More 1™ with Wind Noise Management. In addition, hearing aid users compared Oticon Real with two competitor hearing aids and preferred Oticon Real in terms of loudness of wind noise and clarity of speech in wind. Building upon this work, the present study expanded the investigation with technical measurements comparing Oticon Real with WHS to premium solutions from three high-end competitors with their wind noise management system in the maximum activation setting. The aim of the study was to evaluate the performance of Oticon Real and competitor hearing aids across different levels of wind conditions (from moderate to strong). Additionally, we examined the potential benefit to the user related to listening comfort and speech clarity in windy conditions.

Methods: Testing hearing aids in wind

To simulate windy conditions in our sound studio, a wind generator producing a steady and laminar wind flow was used. A head-and-torso-simulator (HATS) was placed 20 cm in front of the wind generator's outlet pipe. The left ear of the HATS was aligned with the centre of the wind outlet. Hearing aids (Oticon Real 1 and three top competitors) were fitted to both ears of the HATS to allow potential activation of binaural features in the different hearing aids, and measurements were conducted in the left ear, which was exposed to a stronger and more controllable wind flow. Additionally, a speech signal was played through a loudspeaker positioned on the left side of the wind generator, 120 cm away from the HATS, to simulate a face-to-face conversation under windy conditions. The speech was a brief English dialogue between a woman and a man and was calibrated to 80 dB sound pressure level (SPL) at the centre position of the HATS, to mimic the natural tendency of people to raise their voices when speaking in noisy situations.

With the setup outlined in Figure 1, we recorded the output of the hearing aids using the HATS. Recordings of wind noise alone were used to evaluate listening comfort, using a measure of predicted loudness. Recordings of speech in the presence of wind noise were used to assess speech clarity. Three different wind conditions were investigated, corresponding to wind speeds of 5 m/s, 7 m/s and 9 m/s. These selected wind speeds are realistic in many parts of the world. At 5 m/s, corresponding to wind force 3 on the Beaufort scale, a gentle to moderate breeze is experienced, capable of moving leaves and small twigs in trees. The 7 m/s represents a moderately strong wind (wind force 4 on the Beaufort scale), which can move small branches on trees and pick up dust and loose papers from the ground. Finally, 9 m/s, corresponding to wind force 5 on the Beaufort scale, is a breeze strong enough to move large branches in trees. The moderate wind speeds of 5 and 7 m/s are commonly encountered when walking outdoors, while the strong 9 m/s winds are more likely to be experienced during outdoor activities such as cycling or during rough weather.

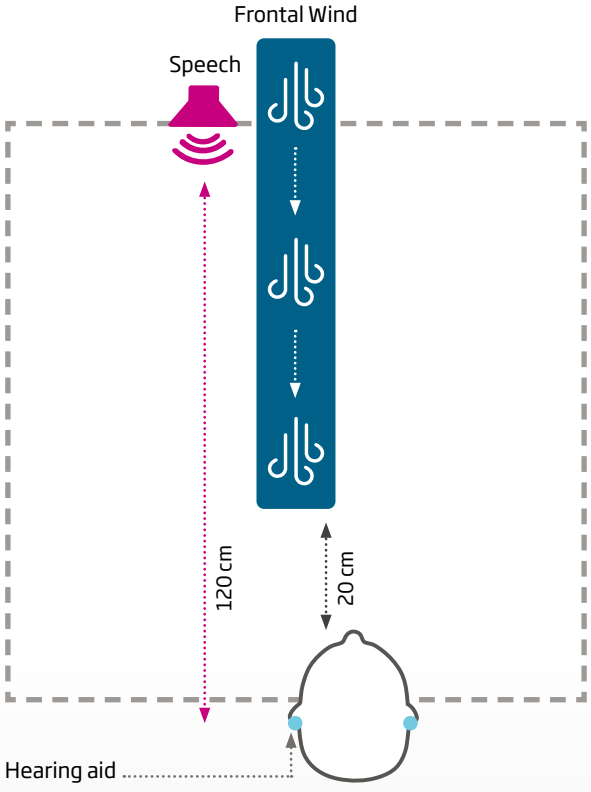

Figure 1: Schematic illustration of the test setup with the wind generator, loudspeakers, and hearing aids.

Oticon Real hearing aids and three of the latest premium competitor hearing aids were adjusted with each manufacturer's proprietary rationale for a mild to moderate hearing loss according to an N2 standard audiogram (Bisgaard et al., 2010). All features were kept to the default prescribed settings, except the feedback management feature which was turned off in all hearing aids to ensure the technical validity of the measurements. Oticon Real was evaluated with WHS on. For competitors that allow different settings for wind noise reduction, the maximum activation setting was chosen.

Providing a more comfortable listening experience in wind

One of the main goals of wind noise management systems is to minimize the wind noise level as much as possible. As wind noise is generally undesired, its reduction provides users with an improved, more comfortable listening experience, particularly in challenging, windy conditions. Evaluating the wind noise level at the hearing aid output can thus be used to assess the performance of hearing aids in windy situations. To do this, we calculated the broadband wind noise levels from 2-minute recordings at the three tested wind speeds.

Figure 2 shows the measured wind noise levels for Oticon Real and for the three competitor hearing aids for all tested wind conditions. At all wind speeds, the wind noise levels were lower in Oticon Real than in competitor hearing aids. The results showed that users can expect approximately 6 to 13 dB less disturbing wind noise in Oticon Real (see Table 1).

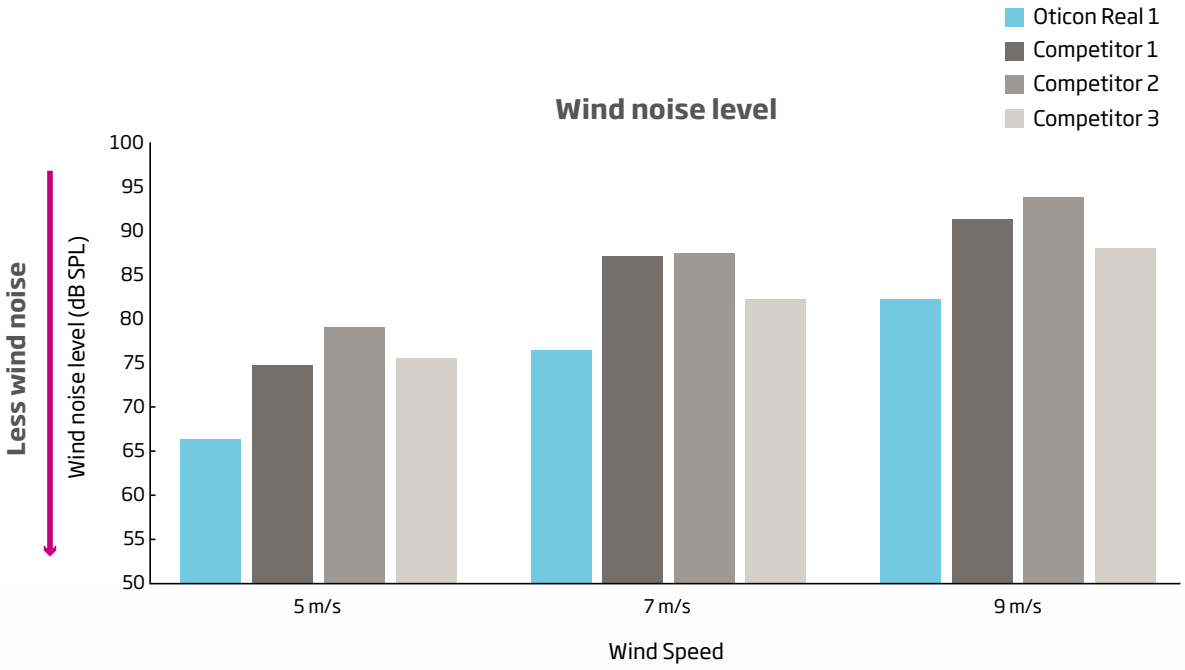

Figure 2: Broadband wind noise level in dB SPL at three different wind speeds for Oticon Real 1 and the three tested competitors.

Wind noise level difference in dB	5 m/s	7 m/s	9 m/s
Oticon Real vs. competitor 1	-8.4	-10.7	-9.0
Oticon Real vs. competitor 2	-12.8	-11.1	-11.5
Oticon Real vs. competitor 3	-9.2	-5.9	-5.8

Table 1: Wind noise level difference in dB between Oticon Real 1 and the three tested competitors at three different wind speeds.

The results clearly show that the wind noise levels were lowest in Oticon Real. To better relate the lower noise levels to user perception, we looked at loudness estimates. Loudness is the perceptual quantity that relates to the physical sound pressure level and it is measured in sones (ISO 532, 1975). This is a linear scale that represents the perceived loudness of a sound. In simpler terms, when the sone value of a sound is doubled, the sound will be perceived to be twice as loud. Based on this, we evaluated the loudness of wind noise as an indicator of the listening comfort provided by the hearing aids to users in windy conditions. For wind noise, lower loudness indeed contributes to a more comfortable listening experience.

We calculated the predicted loudness in sones according to the Moore-Glasberg method described in ISO 532-2 (ISO 532-2, 2017). The Moore-Glasberg loudness model is a mathematical model used to estimate the perceived loudness of sounds by considering the frequency-specific sensitivity of the human ear. Figure 3 shows the predicted loudness estimated from the wind noise recordings at all wind speeds for Oticon Real and the tested competitors. The results showed that the predicted loudness of wind noise in Oticon Real is lower than in all three competitors at all tested wind speeds. In fact, wind noise in Oticon Real was predicted to be 20 to 41% less loud than in the tested competitors (see Table 2).

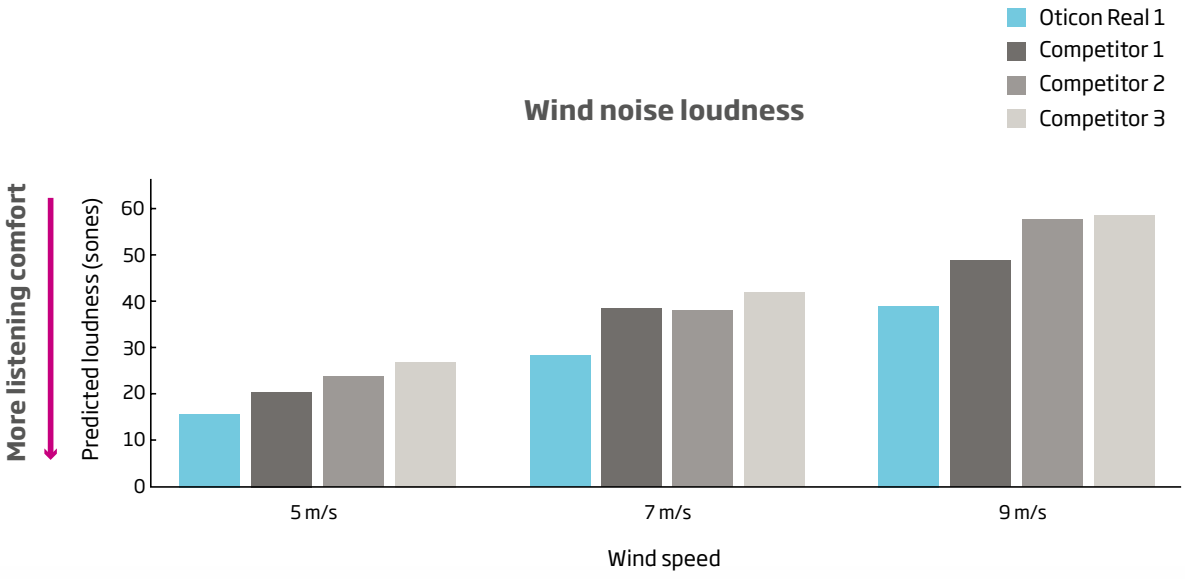

Figure 3: Predicted loudness of wind noise in sones at three different wind speeds for Oticon Real 1 and the three tested competitors.

Predicted loudness difference in %	5 m/s	7 m/s	9 m/s
Oticon Real vs. competitor 1	-23%	-27%	-20%
Oticon Real vs. competitor 2	-34%	-26%	-32%
Oticon Real vs. competitor 3	-41%	-33%	-34%

Table 2: Difference in predicted loudness of wind noise in percentage (%) between Oticon Real 1 and the three tested competitors at three different wind speeds.

Note that the predicted loudness calculated in the current study was based on a normal-hearing model. For a hearing aid user, the perceived loudness will also depend on the individual hearing loss. It is known that cochlear hearing loss typically increases the sensitivity for changes in level, such that loudness curves are steeper. This effect is called loudness recruitment (Moore & Glasberg, 2004). As a result, the differences in perceived loudness with changes in level may be even more noticeable for people with hearing loss. Therefore, the predicted loudness comparisons reported here may be considered conservative.

Overall, the evaluation of sound pressure level and predicted loudness indicated that users can anticipate a more comfortable listening experience in wind with Oticon Real with WHS on compared to the tested competitors, even when their wind noise management features are set to the maximum.

Providing better speech clarity in wind

Wind noise can also affect speech clarity during outdoor activities, especially in situations where the wind noise level is high. Wind noise can mask the speech signal, making it difficult for users to effectively follow conversations or understand important information. The hearing aid's ability to preserve speech clarity while reducing wind can be quantified by measuring its output signal-to-noise ratio (SNR). A higher SNR indicates that the hearing aid is better at separating speech from wind noise, resulting in clearer and more understandable speech for the user.

The output SNR was measured by recording speech in the presence of wind noise using the setup depicted in Figure 1. To calculate the output SNR, the target speech and the wind noise were separated using a modified version of the phase inversion method by Hagerman & Olofsson (2004). The target speech was reconstructed by applying an averaging method to 64 repeated recordings of the same speech sequence. The SNR was calculated in third octave bands from the separated speech and wind signals. The SNR was weighted in all frequency bands with the Speech Intelligibility Index weights (ANSI S3.5, 1997) for each band's centre frequency, before calculating the broadband SNR.

The reliability of the averaging method for separating speech from wind noise decreases as wind noise level or wind speed increases. Due to this, the output SNR was analysed only for a moderate wind speed of 5 m/s, for which it was possible to reconstruct the speech from the recording reliably using 64 repetitions.

The output SNR for Oticon Real and for all three tested competitors is shown in Figure 4. In Oticon Real, the output SNR was 4.8 dB, which is 0.8 dB higher than in competitors 1 and 2, and 1.5 dB higher than in competitor 3. This indicates that Oticon Real provides the most access to speech in wind and a better speech clarity at moderate wind speeds.

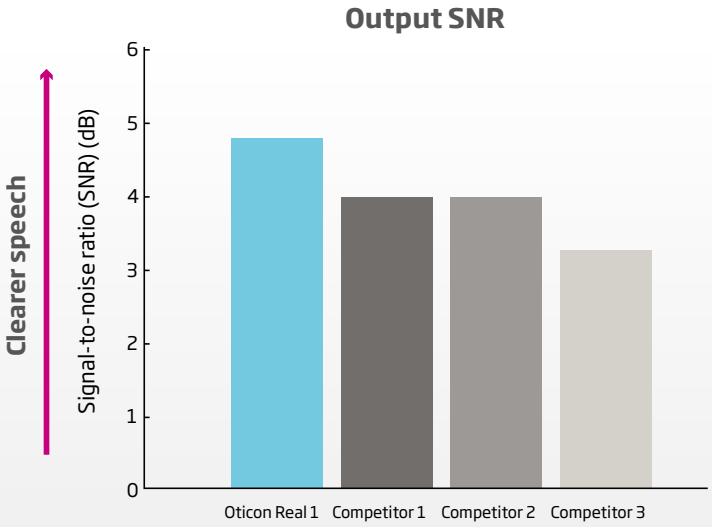

Figure 4: SII weighted SNR at the hearing aid output for Oticon Real 1 and three competitors, measured at 80 dB SPL speech level and 5m/s wind speed.

The SNR calculations show that Oticon Real preserves more speech than the competitors while attenuating the wind noise. Next, we quantified how this translated to improved speech intelligibility. The Speech Intelligibility Index (SII) is a measure of predicted speech intelligibility that evaluates the degree to which speech can be understood based on the audibility of the speech signal (ANSI S3.5, 1997). The SII is calculated by comparing the spectral content of the speech signal with the spectral content of the noise and the frequency-dependent hearing threshold of the user, accounting for self-masking effects, and applying importance weighting to the frequency bands according to ANSI S3.5-1997. A higher SII indicates that more of the information in the speech signal is audible and therefore more likely to be understood.

To analyse the spectral content of speech and wind, we separated wind and speech from the recordings using the method described above for the output SNR measurements. We then calculated the SII for a moderate hearing loss to reflect a user's hearing ability in a realistic way and to obtain meaningful SII scores. It is important to keep in mind that each individual hearing loss can be different, which can result in different intelligibility.

The calculated SII for all four hearing aids is shown in Figure 5. Oticon Real obtained an SII of 52.2%, which is 6 to 11 % points higher than the competitors. Note that, in such a windy situation, a normal-hearing person without hearing aids would only reach SII scores of around 72%. The results indicate that Oticon Real provides more access to speech cues in wind than the tested competitors.

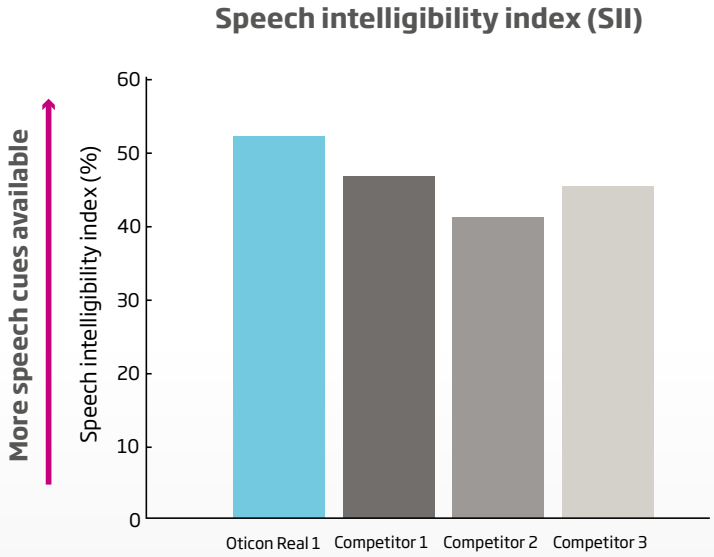

Figure 5: Speech Intelligibility Index for Oticon Real 1 and three competitors. The wind speed was 5 m/s and the speech level 80 dB.

A real advantage over the competition

Let's now relate the above results to the perceptual study in the wind tunnel reported in Gade et al. (2023). In that earlier study we had 10 hearing aid users blindly comparing Oticon Real 1 to two competitors, rating experienced loudness and speech clarity. Overall, there was a trend for wind noise to be perceived as less loud and speech to be clearer compared to both competitors. Due to the relatively small number of subjects and the relatively large inter-subject variability, not all differences were statistically significant. However, Oticon Real still clearly outperformed one competitor in terms of loudness and the other one in terms of speech clarity. Note that, in the perceptual study by Gade et al. (2023), default settings were used for all adaptive features, including the wind noise feature. In the present study, we added a third competitor device and increased the wind noise feature to its maximum setting if multiple levels were available, to ensure that we were capturing the highest performance that each of our competitors could deliver. Therefore, the technical measurement results presented here further strengthen the results of the perceptual study. Taken together, these studies provide objective and clinical evidence that, compared to three top competitors, Oticon Real produces lower wind noise levels, resulting in lower perceived loudness in moderate to stronger wind, while still providing superior speech clarity in windy situations.

Summary and conclusions

This technical study investigated the performance of Oticon Real with Wind & Handling Stabilizer against three top competitor hearing aids with their noise management systems in the maximum setting. Oticon Real was found to outperform the three tested competitor hearing aids in different domains:

- In the presence of wind, the wind noise level at the hearing aid output is lower in Oticon Real than in all three competitors.
- Oticon Real provides a lower predicted loudness of wind noise than all three competitors.
- Oticon Real provides a larger contrast between speech and wind noise than all three competitors.
- Oticon Real allows access to more speech cues in the presence of wind than all three competitors.

Overall, the new technical evidence demonstrates Oticon Real's state-of-the-art performance in terms of improved listening comfort and speech clarity in windy situations.

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