WHITEPAPER
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SuddenSound Stabilizer – Evidence and user benefits

Balanced rapid adaptation to sudden sounds for more clarity and less effort

ABSTRACT

Sudden sounds are very common in everyday listening environments. For hearing aid users, sudden sounds need to be processed in a way that makes them comfortable and not disturbing but also preserves them as distinct natural elements of the sound scene. Sudden sounds come in a wide variety of shapes and sizes. They can be softer or louder depending on the situation. Moreover, sensitivity to sudden sounds varies greatly between people. This whitepaper presents a novel strategy to process sudden sounds in Oticon hearing aids, designed to allow enough flexibility to reflect the real-world diversity in both sudden sounds and patient sensitivity.

The SuddenSound Stabilizer in Oticon Real™ uses balanced and rapid adaptation to sudden sounds and is part of MoreSound Amplifier™ 2.0. Active in both simple and complex situations, this new solution includes two new settings to accommodate more personalization to individual user needs. Technical investigations showed that SuddenSound Stabilizer could provide a wider range of attenuation patterns than existing solutions, while acting instantly and preserving the detailed waveform of sudden sounds with very high integrity. The two new settings were found to attenuate sudden sound peaks significantly more than the maximum settings available in corresponding algorithms used in the previous generation of Oticon devices and in two premium competitor hearing aids. SuddenSound Stabilizer also improved access to speech in the presence of sudden sounds for all activation settings. Finally, a clinical study demonstrated that SuddenSound Stabilizer significantly reduced listening effort and the tendency of participants to give up when listening to speech in the presence of sudden sounds, without further affecting speech understanding.

EDITORS OF ISSUE

Sébastien Santurette, Mette Brændgaard, Junzhe Wilson Wang and Kang Sun
Centre for Applied Audiology Research, Oticon A/S

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Introduction

We are surrounded by sounds. Loud sounds. Quiet sounds. But sudden sounds, loud or quiet, are among the most challenging for hearing aids to handle. Traditional systems handle sudden sounds in different ways. Some traditional algorithms are capable of handling both softer and louder sudden sounds, whereas others are only capable of handling loud sudden sounds such as door slams and breaking cutlery (Keshavarzi et al., 2018; Liu et al., 2012). One of the solutions used in traditional systems for handling sudden sounds is to decrease the gain to modify the sudden sound. Unfortunately, this often results in decreasing gain for the following speech sounds which may then be rendered inaudible (Keshavarzi et al., 2018). Another way to handle sudden sounds is through peak clipping. Peak clipping handles only the sudden sounds that are loud enough to reach the threshold for clipping (Keshavarzi et al., 2018). The latter approach also introduces distortion to the signal which reduces sound quality and speech intelligibility (Dillon, 2001).

Challenged hearing aids too often translate into challenged patients. A significant number of patients report being challenged daily by sudden sounds (Gade et al., 2023). Imagine a keyboard clacking or a colleague tapping their pen on a table. In an open office, you may barely notice these sounds due to other background sounds. But in an empty office or hushed meeting room, such sounds can be distracting, even disruptive even though they are not very loud. Loud sudden sounds of course also need to be handled in order not to be distracting or even uncomfortable.

In Oticon Real, all sounds are processed through MoreSound Intelligence™ 2.0 with Wind & Handling Stabilizer (see Figure 1). The sound input is clarified to provide the full sound scene with clear contrast and balance. The balanced output is passed to MoreSound Amplifier 2.0 (MSA 2.0) with SuddenSound Stabilizer (SSS) for precise and balanced amplification. The whole process is supported by MoreSound Optimizer™, which eliminates feedback. For more information on RealSound Technology™ and Wind & Handling Stabilizer, see Gade et al. (2023).

Now, with our new SuddenSound Stabilizer, part of MSA 2.0, we can handle more subtle sudden sounds across a range of environments while also handling loud sudden sounds more precisely. This enhanced ability to handle a wider spectrum of sound is especially relevant when we know that seven out of ten hearing aid users are challenged by disruptive sounds and that nine out of ten hearing care professionals have first-hand experience of such challenges (Gade et al., 2023).

To get a better understanding of why the numbers are so high, we calculated the number of times SuddenSound Stabilizer activates during a typical 16-hour day. A variety of real-life sound scenes were played for the Oticon Real

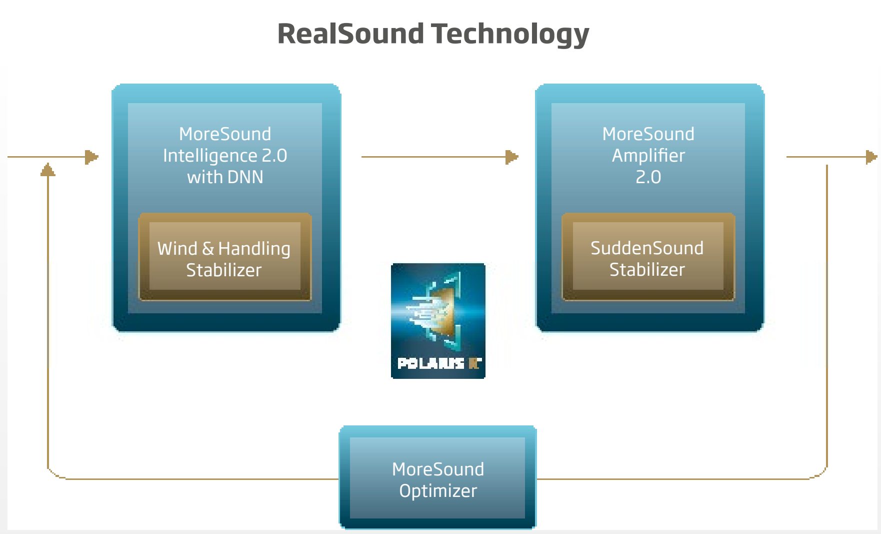

Figure 1: SuddenSound Stabilizer is part of MoreSound Amplifier 2.0.

hearing aid and the number of SuddenSound Stabilizer activations were then tallied. Sound scenes included, for example, an amusement park with music, a lawn mower, sports situations, a dinner party, office and living room situations. The different sound scenes were categorized from simple to very complex.

The activity level of SuddenSound Stabilizer in the different sound scenes was distributed across a 16-hour day, based on data from Humes et al. (2018). Humes et al. state, based on hearing aid logging data, that hearing aid users spend about 60% of a typical day in quiet or speech only situations and 40% of a typical day in moderately complex to complex environments. Figure 2 shows an example of sound distribution throughout a typical day. Our investigation revealed that SuddenSound Stabilizer was activated up to 500,000 times per day, depending on individual hearing aid settings. The same calculation was done for Oticon More™ with Transient Noise Manager set to Medium. In comparison, Oticon Real detected and handled 70% more sudden sound peaks than Oticon More.

SuddenSound Stabilizer handles a wide variety of environmental sounds. Our new system constantly analyzes input sounds and the hearing environment, then dynamically decides how to handle all sounds before the sound is perceived by the patient. The result is a more balanced sound scene in which sudden sounds are distinct and audible with less distraction and disruption.

Balanced rapid adaptation to sudden sounds

SuddenSound Stabilizer (SSS) finalizes the processing in MSA 2.0 and ensures that all sudden sounds are amplified correctly. Sudden sounds are sounds with a very rapid onset and offset and they are often broadband in their frequency content. Such quick onset sounds require special monitoring to make sure they are neither over, nor under-amplified. The goal of the SuddenSound Stabilizer system is to ensure sounds are audible, but not disruptive, annoying, or uncomfortable.

Processing flow

The processing of sound in SuddenSound Stabilizer is shown in Figure 3. The following description is based on the steps in the figure.

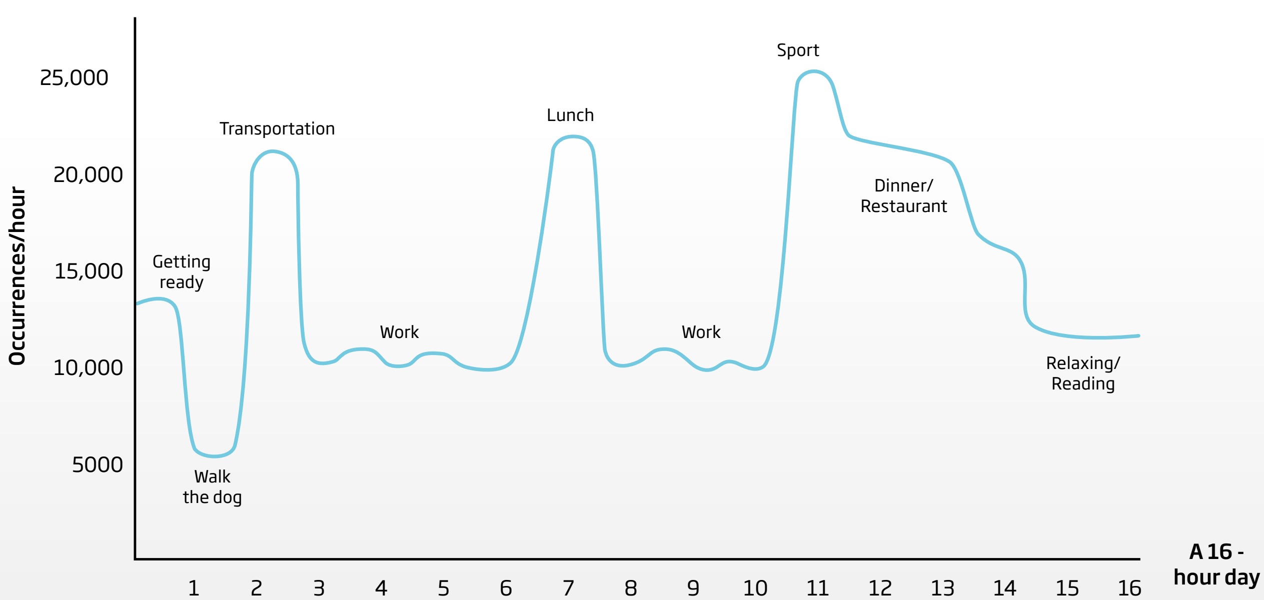

Figure 2: SuddenSound Stabilizer activity during a 16-hour day with different activities during work and time off.

Step 1: The SSS calculation is based on the measurements done by a fast level detector. The fast level detector measures amplitude levels across frequencies over time. These measurements are made on the amplified signal (provided by the first part of MSA 2.0) and reflect all the dynamic changes in the sound scene for the entire frequency range. The measurement is then passed on to a slow detector which uses a low-pass filter to create a slower, varying level estimate. The difference between the two measurements is computed to see where the fast level estimation is higher than the slow estimation. The variations indicate possible sudden sounds. Any peaks are a potential sudden sound that needs to be handled by the system. The low-pass filter is dependent on the personalized settings in the hearing aid (see Personalized settings below). By changing the low-pass filter coefficient, a bigger or smaller difference between the fast and slow estimates is created compared to the default setting, e.g., when a higher personal setting is chosen by the patient, a higher number of sudden sounds are detected and perceived as more impactful by SSS. More help is thus applied by the system for patients who require it.

SSS runs constantly and can detect and handle up to 500,000 sudden sounds daily. The quantity of sounds is dependent on the hearing aid user's listening environment and how long they wear their hearing aids. The measurement forms the basis for the handling of sudden sounds.

Step 2: The positive peaks are reversed into negative gain values based on the user's individual hearing aid settings creating the sudden sound map.

Steps 3 and 4: Sudden sounds are louder than the average surrounding sound. This does not necessarily mean that the sound is loud in absolute terms, just that it is loud within the context of the current environment. For example, typing on a keyboard will create peaks in a quiet environment and be disrupting and possibly annoying, but not loud enough to be painful or uncomfortable. On the other hand, in a loud environment typing on a keyboard will not be louder than the average surrounding sound and hence it will not be identified as a sudden sound. Therefore, the input level from the microphone is taken into account in the final gain adjustment for the sudden sounds. This ensures that sudden sounds are attenuated adequately according to the sound environment. Thus, sudden sounds in loud environments will be attenuated more than sudden sounds in quiet environments, as sudden sounds in loud environments would otherwise become uncomfortably loud.

Step 5: The final gain adjustments for sudden sounds are then distributed across the 24 processing channels. The attenuation is applied instantaneously as soon as the sudden sound starts and released as soon as the sound ends so as not to attenuate amplification needed for other sounds before and after the sudden sound.

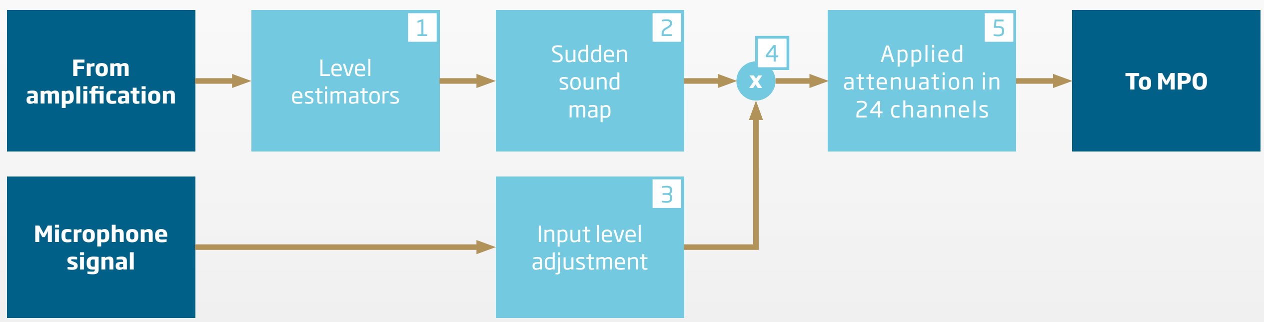

Figure 3: SuddenSound Stabilizer processing. For explanation see the text.

Personalized settings

SuddenSound Stabilizer has six different settings to personalize the performance of the hearing aid to a patient's individual needs. The settings range from Off to Max. The following settings are available: Off, Low, Medium, High, Very High, and Max. Medium is the default setting for all fittings. The individual setting should be chosen based on feedback from the patient – the more sensitive to sudden sounds they are, the more a setting towards Max should be chosen. For more suggestions on how to optimize fittings for this user group please refer to Preszcator and Løve (2023).

The actual attenuation will depend on different variables. The maximum attenuation for the different settings is, for example, up to 10 dB for the Low setting and up to more than 30 dB for the Max setting. Figure 4 shows an example of the differing amounts of attenuation based on the different settings. The maximum attenuation cannot be measured in a standard test box setup as some of the variables for getting the maximum attenuation cannot be applied in the test box.

The previous Transient Noise Management (TNM) had four settings: Off, Low, Medium, and High. These four settings do not correspond one-to-one to the settings in SSS. Based on user input from clinical testing, the attenuation for sudden sounds in loud environments has been increased. For clients satisfied with the setting they have today, the setting with the same name is recommended in SSS.

Due to a general preference for stronger attenuation in noisier environments, the settings for attenuating sudden sounds in Special Purpose Programs have also been adjusted. For the Speech in Noise program the attenuation setting has changed from Medium in the old TNM to High

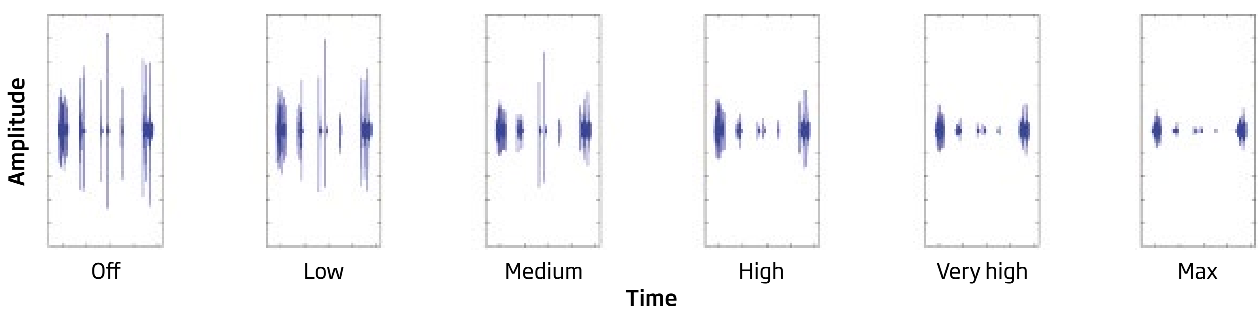

Figure 4: Amplitude of a selection of real-life sudden sounds recorded at the output of the hearing aid for Oticon Real with the different activation settings of SuddenSound Stabilizer from Off to Max.

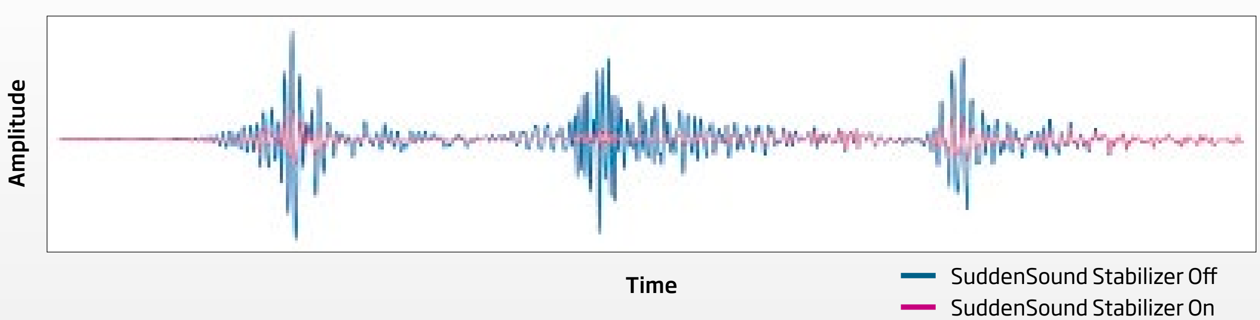

Figure 5: Detailed waveform of three real-life sudden sounds recorded at the output of the hearing aid for Oticon Real with SuddenSound Stabilizer Off (blue waveform) and SuddenSound Stabilizer On in the High setting (red waveform). The time between peaks in the waveform was typically shorter than 1 ms in our measurements.

in SSS; and for the Comfort program the attenuation setting has changed from Medium in TNM to Very High in SSS. In a direct comparison, these changes are audible.

SuddenSound Stabilizer is available for hearing aids on the Polaris R™ platform. The number of settings will vary depending on performance level. The highest number of settings are available for the highest performance level devices. If the default setting in a Special Purpose Program is not available in the hearing aid price point being fitted, the program will default to the highest available setting.

Sudden sound attenuation – Technical performance and benchmark

How the different settings affect sudden sounds

We investigated the technical performance of SuddenSound Stabilizer by recording the output of Oticon Real hearing aids in the presence of real-life sudden sounds in a sound studio. A pair of Oticon Real hearing aids, with gain adjusted to a moderate hearing loss based on an N3 standard audiogram (Bisgaard et al., 2010), was placed on the ears of a head-and-torso simulator (HATS) equipped with highly sensitive microphones at the end of its ear canals. Twenty diverse real sudden sounds, such as the chopping of a knife, the slamming of a door, the dropping of a coin on a table, typing sounds on a keyboard, footsteps, etc., were presented from a loudspeaker towards the front of the HATS. These sudden sounds were selected to reflect the acoustic diversity of sounds encountered by hearing aid users in their daily life, with different numbers of amplitude peaks in their acoustic waveforms and various peak heights. All advanced features in the hearing aids were set to the prescribed default and recordings were obtained for all available settings of the SuddenSound Stabilizer feature.

Figure 4 shows example recordings of five different sudden sounds for all six SuddenSound Stabilizer settings

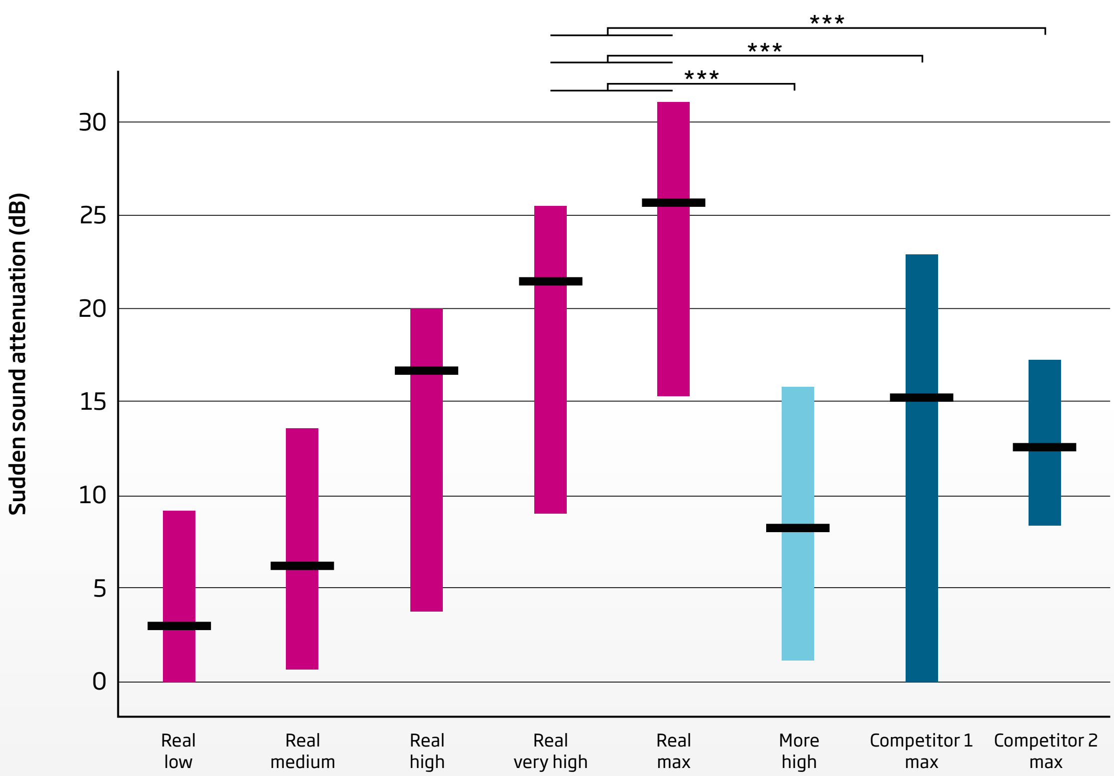

*Figure 6: Measured attenuation ranges in dB for 20 real-life sudden sounds with the different activation settings of SuddenSound Stabilizer in Oticon Real and with the maximum available setting in Oticon More and two premium competitor devices. For each device, vertical bars show the attenuation range and the black horizontal lines indicate the median attenuation value. *** $p < 0.001$.*

from Off to Max. Looking at the height of peaks in the waveforms, it is clearly visible that increasing the activation of SuddenSound Stabilizer progressively attenuates peak height, illustrating that the attenuation of sudden sounds can be adjusted to different levels depending on the user's needs. Zooming in on three examples of sudden sound amplitude peaks, Figure 5 shows the temporal fine structure of the acoustic waveform at the hearing aid output for the Off setting (blue waveform) and the High setting (red waveform). Despite the extremely short time period between consecutive peaks, typically below 1 ms, it can be seen that all peaks in the waveform fine structure are reduced. Even the very first peaks at the onset of the sudden sounds are reduced, indicating that SuddenSound Stabilizer can act so fast as to catch instant sharp increases in sound level. Moreover, while all peaks are clearly attenuated when SuddenSound Stabilizer is active, their precise timing remains unchanged whether the feature is on or off, such that the fine temporal integrity of the sound is very well preserved by SuddenSound Stabilizer.

In order to quantify the attenuation of sudden sounds provided by SuddenSound Stabilizer, peak levels were calculated and compared for its different activation levels relative to the Off setting. The attenuation ranges for the 20 different sudden sounds are shown by the magenta vertical bars in Figure 6, the black line indicating the median attenuation for each of the Low, Medium, High, Very High, and Max settings. These results demonstrate how the attenuation range progressively moves towards higher sudden sound attenuation values as higher settings are chosen and can reach more than 30 dB attenuation in the Max setting. Note the breadth of attenuation ranges for each setting, which reflect the fact that SuddenSound Stabilizer adapts to the characteristics of different sudden sounds, with an attenuation that depends on their original level.

Performance benchmark

Recordings were also obtained for the same set of 20 sudden sounds with three other hearing aids, namely Oticon More and two high-end devices from top competitors. All hearing aids were programmed to the same moderate hearing loss based on an N3 standard audiogram (Bisgaard et al., 2010) using the NAL-NL2 rationale (Keidser et al., 2011) with all features set to default prescription. Only the transient noise management feature was set either to the minimum (Off) or maximum available setting (corresponding to High in Oticon More) and the sudden sound attenuation between these two settings was calculated. As shown by the light blue (Oticon More) and dark blue (competitors) vertical bars in Figure 6, the sudden sound attenuation values obtained for Oticon Real in the Very High and Max settings were significantly higher than those obtained for Oticon More and both competitors in their maximum available setting (all comparisons: $p < 0.001$, Wilcoxon rank sum test with Bonferroni-Holm correction). The two new available settings in Oticon Real, Very High and Max, thus achieved significantly higher median attenuation than the other devices. This indicates that SuddenSound Stabilizer can better cater for the needs of users who show high sensitivity to sudden sounds than Transient Noise Management in Oticon More and the corresponding features in the tested premium competitor devices, allowing better comfort in the presence of sudden sounds.

Improved speech clarity in the presence of sudden sounds

When occurring during speech listening, sudden sounds can compromise the integrity of the speech signal. In a second technical investigation, we measured how SuddenSound Stabilizer in Oticon Real affected speech clarity and how the effect compared to the Transient Noise Management solution in our previous generation of premium hearing aids, Oticon More. For this purpose, we studied how much the activation of each feature made speech stand out from the background in a realistic sound scene with sudden sounds.

We reproduced the ecologically valid speech-in-noise scene shown in Figure 7 in our sound studio. The speech signal was taken from the Danish DAT corpus (Nielsen et al., 2014) with a female speaker played back from the front loudspeaker at 70 dB SPL. The selection of diverse real-life sudden sounds used in the previous section were presented from one of the loudspeakers at 30° azimuth. In addition, four-talker babble noise was presented from 100° and 260° azimuth at either 60, 65, or 70 dB SPL, corresponding to simple, moderate, and complex situations, respectively. The peak level of the sudden sounds was equalized, corresponding to overall sudden sound levels ranging from 70 to 89 dB(C).

A HATS was placed in the center of the setup, 1.6 m away from each loudspeaker, wearing either Oticon Real or Oticon More on both ears. Power domes with the size matching the ear canals were used to prevent sound leakage between the receivers and the microphones. Gain was provided for a moderate hearing loss based on an N3 standard audiogram (Bisgaard et al., 2010) using the NAL-NL2 rationale (Keidser et al., 2011). SuddenSound Stabilizer in Oticon Real and Transient Noise Management in Oticon More were set to either the Off, the default (Medium), or the maximum available setting. All other features were set to default prescription.

The output SNR was calculated by applying the phase inversion method (Hagerman & Olofsson, 2004) for each condition tested in Oticon Real and Oticon More. All output SNRs were weighted with the Speech Intelligibility Index (SII) in each frequency region according to the ANSI S3.5-1997 (1997) standard. We computed the difference in SII-weighted output SNR between the SSS Off, default (Medium), and maximum (Max) settings in Oticon Real, and between the TNM Off, default (Medium), and maximum (High) settings in Oticon More, to show the SNR enhancement provided by the default and maximum SSS/TNM activation levels.

Figure 8 shows the improvements in SNR provided by SSS in Oticon Real and TNM in Oticon More hearing aids in the default and maximum settings relative to Off. Oticon Real was found to provide additional SNR benefit in both cases, with enhancements of about 1.5 dB in the default setting and up to about 3 dB in the maximum setting. Such enhancements were observed for all three tested situations, from simple to complex. Results from additional

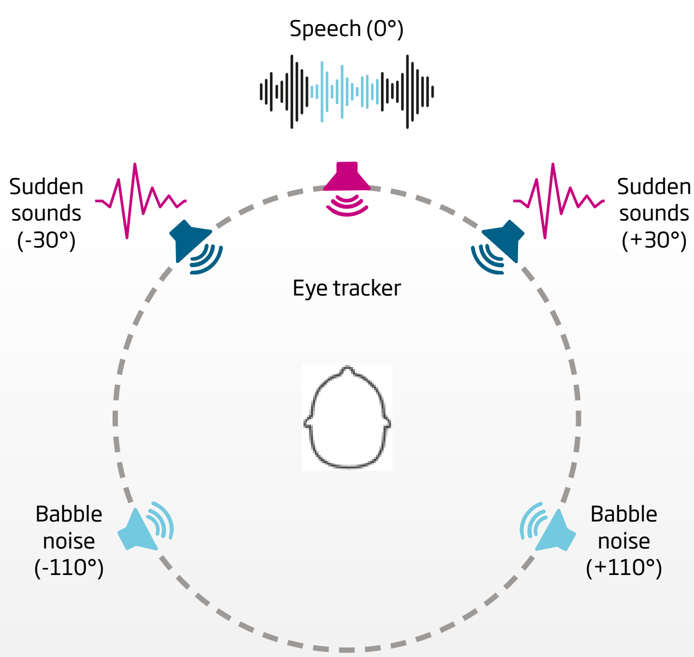

Figure 7: Test setup for the output SNR measurements and the clinical study, with speech presented from the front, sudden sounds slightly to the side, and background babble noise from the back sides.

test conditions with the other available settings in Oticon Real showed that the average SNR enhancement ranged from 0.7 dB in the Low setting to 2.7 dB in the Max setting. These findings indicate that activating SSS in Oticon Real improves speech clarity in the presence of sudden sounds for all available settings and outperforms TNM in Oticon More in terms of speech clarity for the Medium to Max settings. This is because SSS is able to provide sudden sound attenuation without compromising the adequate amplification of speech, even when these occur simultaneously.

Reducing listening effort while preserving speech understanding

Sudden sounds occur every day and are an integral part of our lives – birds singing, clocks ticking, cutlery sounds during dinner, etc. The information provided by such sounds enriches our auditory sensation and awareness of our surroundings. Desired or not, sudden sounds come with our activities and contribute to the context of the situation. Sudden sounds could also redirect our attention. Imagine you are having an engaged conversation. The sound of glass breaking, of a door slamming, or of keyboard typing could distract your focus from the conversation. Ideally, hearing aid users would like to preserve the auditory information carried by the sudden sounds without being disturbed by them.

In a clinical study, we investigated the effect of SuddenSound Stabilizer while 29 hearing aid users with mild to moderate symmetrical hearing loss performed a speech recognition task during which sudden sounds were presented. The outcome measures included speech intelligibility, pupil response as an index for listening effort, and subjective assessments.

Methods

All participants were fitted with Oticon Real hearing aids using the gain prescribed by the VAC+ rationale. All advanced features were set to default prescription, except SSS which was either on or off. The test setup shown in Figure 7 was used, with target speech presented from a single frontal loudspeaker, consisting of 2-second long sentences from the Danish DAT corpus (Nielsen et al.,

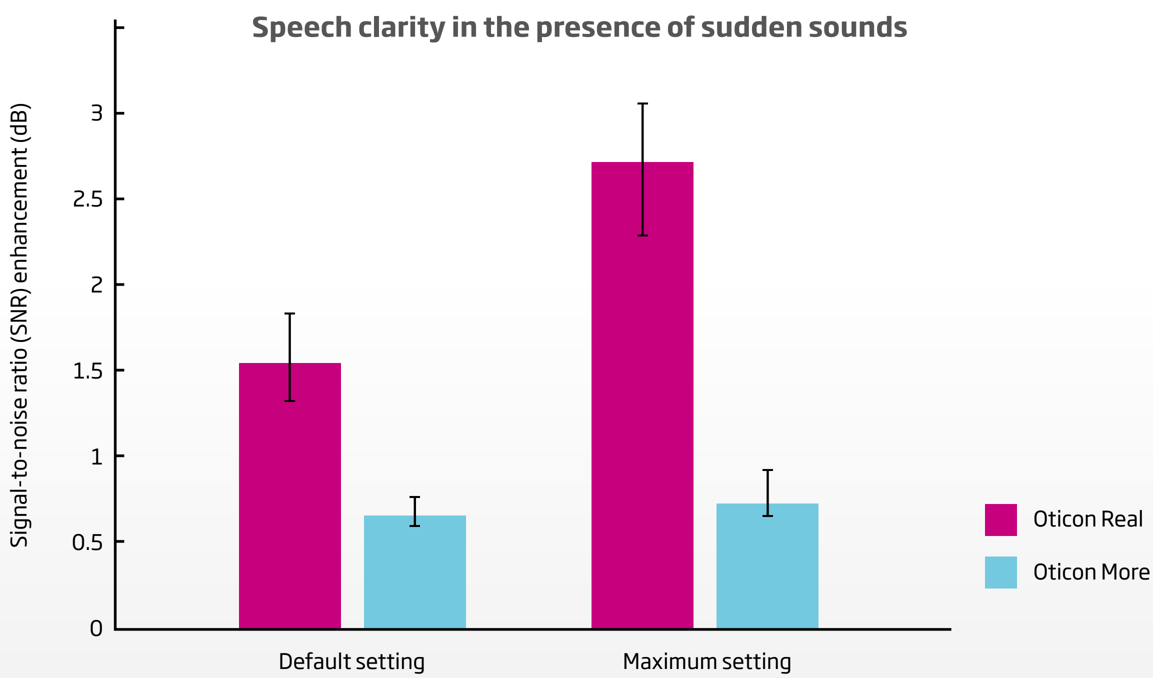

Figure 8: Output SNR enhancement when activating SuddenSound Stabilizer in Oticon Real (magenta bars) and Transient Noise Management in Oticon More (light blue bars) in the default (medium) and maximum available prescription settings. Bar height indicates the average improvement and error bars indicate the full improvement range observed in the measurements across the simple, moderate, and complex situations.

2014). The background noise was presented from ±110° azimuth, with 4-talker babble noise presented from each side. The sudden sounds were presented from ±30° azimuth. When a sudden sound occurred, it had an equal chance of coming from either of the two loudspeakers.

The task was to repeat the two keywords in a DAT sentence, occurring from around 0.8 s to 1.8 s after sentence onset. The same set of real-life sudden sounds as in the technical investigations reported above was used. They were all 1 second long. In each trial, one sudden sound randomly chosen from the set appeared together with the keywords during the sentence. The target speech level was fixed at 70 dB(C), while the peak level of the sudden sounds was equalized, corresponding to overall sudden sound levels ranging from 70 to 89 dB(C). The background noise level was individually adjusted so as to ensure that all test participants achieved 80% speech intelligibility (indexed by correctly reported keywords) when no sudden sounds were present.

This study adopted a two-by-two design. SuddenSound Stabilizer was either set to the Off or the High setting and sudden sounds were either present or absent. All four combinations of SuddenSound Stabilizer setting with sudden sounds presence were tested with at least 20 sentences each, in a random and balanced order. For each of these four conditions, speech understanding and pupil responses were recorded. A subjective questionnaire was also administered, comparing the listeners' tendency to give up during the task on a scale from 0 to 10 between the two SSS settings.

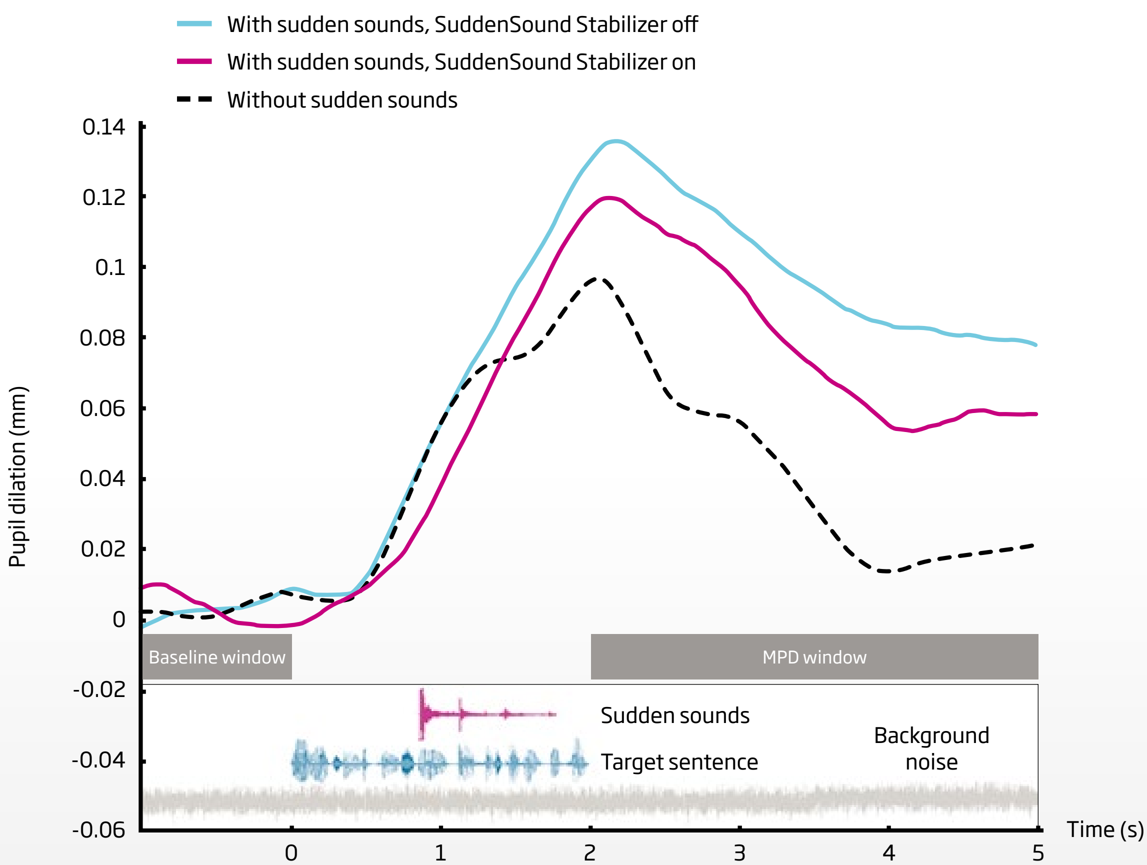

Figure 9: Aggregated pupil dilation (baseline-corrected) across the course of a trial. Pupil traces and the stimulus time course are indicated in the figure. The magenta and light blue curves show pupil dilation in the presence of sudden sounds for SSS on and off, respectively. The dashed black curve shows pupil dilation in the absence of sudden sounds (average of SSS on and off conditions). The time windows used for baseline and mean pupil dilation (MPD) calculations are also shown.

Results

Speech understanding

Speech understanding was calculated as the percentage of correctly repeated keywords for each condition. During the test phase of the experiment, the average speech understanding in the absence of sudden sounds was at 86%. When sudden sounds were present, the average score decreased to 60% due to the masking effect of sudden sounds on the target keywords. However, independently of whether sudden sounds were present or not, the activation of SuddenSound Stabilizer did not have any significant effect on speech understanding. This was confirmed by a generalized linear model statistical analysis showing that the effect of sudden sound presence on keyword recognition scores was significant ($p < 0.001$), while the effect of SSS setting was not ($p = 0.633$).

Pupil responses

Following the procedure described in Wendt et al. (2017), the aggregated baseline-corrected pupil dilation across the course of a trial is shown in Figure 9. The colored curves show the pupil responses for conditions where sudden sounds were present and SSS was either on (magenta curve) or off (light blue curve). The dashed black curve shows the average pupil response over conditions where sudden sounds were absent. Consistent with the literature (e.g., Ohlenforst et al., 2018; Wendt et al., 2017), pupil dilation increased at sentence onset, reaching a maximum value, and decreased progressively again towards baseline after sentence offset, illustrating the change in listening effort during the task. When sudden sounds were presented together with the sentence keywords, turning on SuddenSound Stabilizer yielded a reduced pupil response (comparing the light blue and magenta curves), indicating reduced effort allocation. When no sudden sounds were present at all, pupil responses were the lowest (comparing the dashed black and colored curves). As expected, the sudden sounds overlapping with speech required the participants to allocate more effort to the task.

Three parameters were used for statistical analysis of pupil traces: the baseline pupil dilation, the mean pupil dilation (MPD) from sentence offset (see time window in Figure 9), and the peak pupil dilation (PPD), i.e., the highest point of the pupil trace. A generalized linear model was applied on the three parameters with test participants as random factor. While no significant differences were found for the baseline ($p > 0.05$), both MPD and PPD were significantly increased by the presence of sudden sounds ($p < 0.003$). When turning on SuddenSound Stabilizer in the presence of sudden sounds, both MPD and PPD decreased significantly ($p < 0.05$), indicating decreased listening effort. Overall, the MPD decreased by 22% when activating SSS relative to the highest mean pupil size in the SSS Off condition. In contrast, when sudden sounds were absent, the SuddenSound Stabilizer setting did not significantly affect MPD nor PPD. Overall, these results suggest that SSS significantly reduces listening effort during speech recognition when sudden sounds are present.

Subjective assessment

A repeated measures analysis of variance was used to analyze the subjectively reported tendency to give up during the listening task. Enabling SuddenSound Stabilizer was found to significantly reduce the likelihood of hearing aid users to give up during this task ($p < 0.05$). This suggests that participants remained more engaged in the listening task when SSS was on than when it was off.

Summary

This clinical study investigated the effect of SuddenSound Stabilizer during a speech recognition task both in the presence and absence of sudden sounds. The results indicated that:

- enabling SuddenSound Stabilizer did not affect speech understanding
- enabling SuddenSound Stabilizer reduced pupil response by 22% when sudden sounds were present during a speech recognition task, indicating a significant reduction in listening effort
- enabling SuddenSound Stabilizer reduced the likelihood of participants to give up listening to the speech.

References

1. ANSI (1997). ANSI S3.5-1997, American National Standard methods for the calculation of the Speech Intelligibility Index (American National Standards Institute, New York).
2. Bisgaard, N., Vlaming, M. S., & Dahlquist, M. (2010). Standard audiograms for the IEC 60118-15 measurement procedure. Trends in Amplification, 14(2), 113-120.
3. Dillon, H. (2001). Hearing Aids. Thieme Medical Publishers.
4. Gade, P., Brændgaard, M., Flocken, H., Preszcator, D., & Santurette, S. (2023). Wind & Handling Stabilizer – Evidence and user benefits. Oticon Whitepaper.
5. Hagerman, B., & Olofsson, Å. (2004). A method to measure the effect of noise reduction algorithms using simultaneous speech and noise. Acta Acustica United with Acustica, 90(2), 356-361.
6. Humes, L.E., Rogers, S.E., Main, A.K., & Kinney, D.L. (2018). The Acoustic Environments in Which Older Adults Wear Their Hearing Aids: Insights From Datalogging Sound Environment Classification. American Journal of Audiology, 27, 594-603.
7. Keidser, G., Dillon, H., Flax, M., Ching, T., & Brewer, S. (2011). The NAL-NL2 prescription procedure. Audiology research, 1(1), 88-90
8. Keshavarzi, M., Baer, T., & Moore, B.C.J., (2018). Evaluation of a multi-channel algorithm for reducing transient sounds. International Journal of Audiology, 57:8, 624-631, DOI: 10.1080/14992027.2018.1470336
9. Liu, H., Zhang, H., Bentler, R. A., Han, D., & Zhang, L. (2012). Evaluation of a Transient Noise Reduction Strategy for Hearing Aids. J Am Acad Audiol 23, 606-615, DOI: 10.3766/jaaa.23.8.4
10. Nielsen, J.B., Dau, T., & Neher, T., 2014. A Danish open-set speech corpus for competing-speech studies. The Journal of the Acoustical Society of America, 135(1), 407-420.
11. Preszcator, D., & Løve, S. (2023). Oticon Fitting Guide – Sound Sensitivity.
12. 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.

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