ReSound GN

Performance of advanced noise reduction strategies in premium hearing aids in complex listening conditions

Megan Quilter, AuD; Jan Heeren, Dipl. Phys; Charlotte T. Jespersen, MA

Abstract

Premium hearing aids apply Deep Neural Networks (DNN) with a common goal: to address issues with listening comfort and speech understanding in noisy backgrounds. However, the designs of these features differ substantially. Some are used to control the activation of well-known technologies like directionality and digital noise reduction, while others are denoising features that are used directly in signal processing to remove noise from the signal. The Intelligent Focus feature of the ReSound Vivia 9 uses denoising combined with strong directionality. To evaluate important perceptual aspects of Intelligent Focus, it was tested against three other premium hearing aid brands that use DNNs in a complex multi-talker setup with turn taking and interfering speech in the front hemifield. ReSound Vivia 9 with Intelligent Focus outperformed two of the hearing aids from other brands and was on par with the third. ReSound Vivia 9 with Intelligent Focus was also evaluated against the other hearing aid brands in terms of listening effort. All hearing aids tested provided low listening effort.

A frequent gag used by cartoonists through the years is a man wearing hearing aids with a “wife filter” that when activated, would presumably remove the sound of his wife’s voice from his environment. Part of what made this funny for the target audience was the absurdity of having a device that could recognize and suppress a particular person’s voice. Today, this gag is no longer preposterous. In fact, the limitation on such a product feature is not whether it is technically possible but rather whether it would make sense as a hearing aid feature or provide any benefit that would make it worth the processing and battery power required to drive it. Although there likely won’t be any hearing aids with a person-specific filter on the market any time soon, the underlying technology that would enable it is already there and being applied in more universally useful ways. Hearing aids are increasingly being designed to use advanced forms of Artificial Intelligence (AI) to solve real issues that hearing aid users experience. The primary focus of hearing aid designers is on sound quality, listening comfort, and speech understanding in noisy backgrounds.

The ReSound sound philosophy in developing hearing aids has always been to look to natural hearing processes for inspiration in applying new technologies and AI is no exception. We have even turned the designation around to reflect how our concept is different. Intelligence Augmented (IA), captures the idea of the user being empowered by the technology rather than being subject to artificial decision-making by an algorithm. We look for opportunities to combine what the person wearing the hearing aids and their brain do well with what technology does well. While it is common to think of applying technology to help the user, an implication of helping is that it takes a level of control from the user. Our approach combines the strengths of artificial technology with biological processes of the human.

Intelligence Augmented in our hearing aids should help hearing aid users hear better in noise, but it should not interfere with their listening goals. No matter how effective a technology may be in reducing noise, it will never be able to replace the processing abilities of the human brain. The strategies we use to hear in noise go far beyond just receiving the sound with our ears and transmitting it to the brain. We must also divert cognitive resources to focus our attention on various sounds, decide what we are interested in, and use our brains to filter out the rest of the sounds as noise. Hearing aids help most with improving audibility so the sounds can be heard. Beyond audibility, it’s up to the brain to make decisions on what to listen to. A hearing aid cannot replace these higher-level cognitive functions, even with artificial intelligence. Instead, our Intelligence Augmented technology helps ensure the user is receiving the best possible representation of the sounds around them, so their brain can take that upgraded information and use it to listen effectively.

While AI is a broad term covering many levels of sophistication in decision-making by machines, it is often used informally in reference to the most advanced techniques in this area. Premium hearing aids have begun to incorporate features driven by a sophisticated type of AI called Deep Neural Networks (DNN).[2] Briefly, DNNs employ multilayered networks and algorithms that learn using artificial neural networks inspired by human biological neuroscience. So far, DNNs in hearing aids are being used in two broad ways. One is to analyze the listening environment and to automatically activate and control features that support hearing in those environments. Another way DNNs are being used is in the signal processing to drive single channel noise reduction features. Single channel means that the desired sound and the noise are mixed, and the feature must be able to separate them and isolate the desired part of the overall signal. This latter use is often called "denoising".

Denoising can effectively minimize environmental noises while preserving speech, regardless of which direction speech and other sounds come from in relation to the hearing aid user. In complex listening situations where talkers overlap or voices arise from varying locations, noise reduction approaches are often challenged because the hearing aid doesn't know what the hearing aid user wants to listen to. Because denoising is designed to preserve speech anywhere in the hearing aid user's vicinity, it has the potential both to assist and to interfere with following conversations in complex listening environments depending on the listening intent of the hearing aid user. Imagine wanting to focus on a conversation in front of you, but having greater audibility for a loud talker off to the side due to DNN-driven enhancement of that talker. Therefore, the ReSound DNN-based noise reduction feature, Intelligent Focus, is combined with a powerful 4-microphone beamformer as a user selectable setting for specific listening goals. It is meant for situations where the hearing aid user is listening to a single talker or following a conversation with turn-taking talkers in a noisy setting. Listening to a single talker represents a selective attention task, where the listener focuses on one information source and tries to ignore any competing sources. Following a conversation with multiple talkers is a divided attention task where the listener must quickly switch their attention among sources. Both selective attention and divided attention in listening are improved when the location of sources is perceived as different, with the effects being greatest for selective attention.[3] By combining DNN-based noise reduction and strong directionality, two goals are met that can enhance listening: separation of desired speech and interfering sounds by the directionality, and spotlighted speech by the denoising.

While Intelligent Focus has been shown to significantly increase sound quality compared to legacy single-microphone noise reduction,[4] it remains a question how Intelligent Focus might benefit hearing aid users in terms of their ability to follow speech in complex listening conditions. But how can we ensure a test method that reflects the actual experienced benefits? Traditional speech-in-noise tests do not take into account factors that contribute to the complexity of real-life listening situations such as competing talkers, turn-taking and attention. And for them to have sufficient sensitivity where performance is not maxed out, they require low signal-to-noise ratios (SNR) that are not typical of real-life situations. The competing sounds in traditional tests are often speech-shaped noises or multi-talker babble that provide energetic masking. In real life situations, informational masking from non-target talkers is common and can easily cause confusion with the desired speech. Listeners who are tested with traditional methods may show quite good performance yet report that they continue to struggle in their daily communication situations. The Hörzentrum Oldenburg developed the Concurrent Oldenburg Sentence (CCOLSA) test[5,6] to assess aided listening in such situations. It is a speech test with three target talkers, that can be performed for either a divided attention task (following turn-taking talkers) or for a selective attention task (focusing on one talker), while listening conditions stay the same. One attractive advantage of the CCOLSA paradigm is that it is optimized for ecologically valid SNR (typically -1 to +4 dB).

The purpose of this study was to explore benefits of Intelligent Focus using an ecologically generalizable measure. Hearing aids with DNN-based features from three other premium brands were included as industry benchmarks. Testing was done in a complex multi-talker setup with turn taking and interfering speech in the front hemifield. Speech recognition testing for single target talkers (selective attention) and turn-taking target talkers (divided attention) was carried out, as well as subjectively rated listening effort.

Methods

Participants

A total of 20 participants (10 males, 10 females) with symmetric moderate sensorineural hearing loss participated in the study. They were selected to have hearing loss consistent with the standard N3 and N4 audiograms.[7] The participants' median age was 74 years (interquartile range 65 - 79 years) and they were all experienced hearing aid users with a median of 16 years of hearing aid experience (interquartile range: 11 - 27 years). All were current users of premium Receiver-in-the-ear (RIE) hearing aids from various hearing aid brands.

Hearing aids and fitting

The test participants were fitted with a pair of ReSound Vivia RIE hearing aids (VI960S-DRWC) as well as RIE hearing aids from three other premium brands that have advanced features based on a DNN. All four pairs of hearing aids were fitted with receivers based on the test participants' hearing loss and closed ear tips (power domes or sleeve domes). Closed ear tips were chosen to ensure maximum benefit from the hearing aid signal processing in all four pairs of hearing aids. The hearing aids were fitted with each brand's hearing aid program with the DNN-based feature.

Test conditions

The study was set up as a counterbalanced crossover design, where each participant was fitted and tested with all four pairs of hearing aids. To avoid training effects and order effects, trainings for speech recognition tests were performed before data collection and test conditions were randomized. The study was single-blinded, as the investigators were able to identify the hearing aids, but the test participants could not identify the hearing aids they evaluated.

Test material and setup

Speech recognition in noise test

CCOLSA was used for the speech recognition testing. In the CCOLSA, alternate presentations of sentences spoken by one female and two male talkers from the Oldenburg sentence test (OLSA)[8] comprise the speech material. The sentences of different talkers occurred alternately, but with a defined overlap in time across talkers. The female talker was presented from a loudspeaker in front of the participant (0° azimuth) and the male talkers were presented from +/- 22.5°. The test setup is illustrated in Figure 1.

The CCOLSA talkers were presented at levels 4 dB more intense than the test participants' individual speech reception threshold (SRT) for these talkers. The SRTs were measured using the adaptive Oldenburg sentence test, beforehand. The average SNR for the individual SRTs was -4.4 dB (SD 2.0 dB). Overlap times of sentences were also set individually after measuring the individual overlap-time threshold for 50 percent correct responses (mean 361 ms, std. 232 ms or median 378 ms, interquartile range 237-526 ms).

Speech babble noise was presented at the same time as the sentences. The babble noise consisted of a two-talker dialog (male/female) and ISTS.[9] The babble noise was presented at 70 dB A from 45° azimuth.

The speech recognition testing included both a selective attention and a divided attention task. To assess speech recognition with selective attention, participants were instructed to repeat the last word of each sentence for fixed target talkers (20 target words per talker). By fixed, it is meant that the location of the target talker did not change, so the listener knew where to focus. The investigator announced the target talker for the upcoming 20 sentences. After completing these sentences, the next target talker was announced. Responses were given during the ongoing presentation of sentences.

For the divided attention task, target talker switches were included. Each time a sentence started with the name "Kerstin", it indicated the new target talker. Like in the selective attention task, the last word of each sentence was to be repeated. The switches in target talker occurred every 15-25 seconds (7 times per talker, 21 times in total). Responses were given during the ongoing presentation.

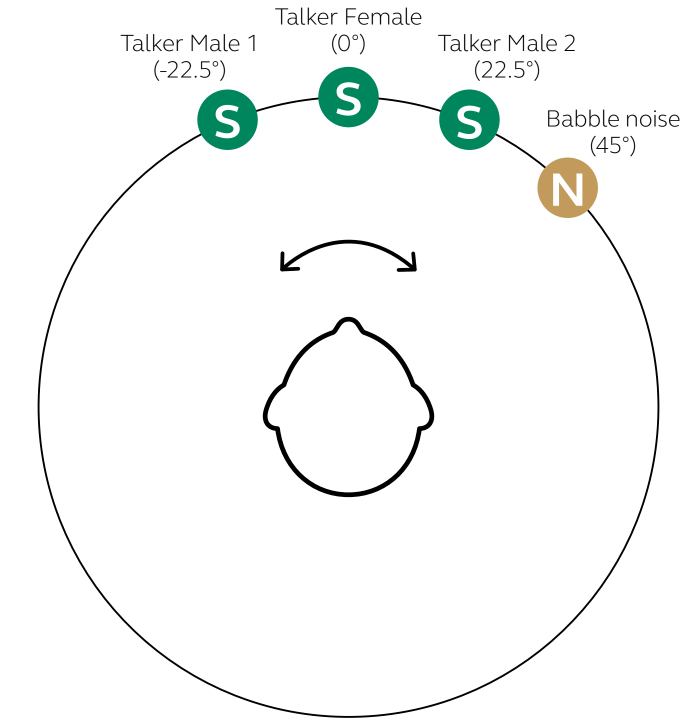

Figure 1. Illustration of test setup used for speech recognition testing.

ACALES Test

The Adaptive Categorical Listening Effort Scaling (ACALES) Test[10] asks participants to rate listening effort while listening to the OLSA sentences. The participants rated the perceived listening effort on a scale from 1 (no effort) to 13 (high effort) on a touch screen. SNR was adjusted adaptively in order to collect ratings for all categorical units of the scale.

The OLSA sentences were presented from the front at 0° azimuth while ISTS was presented at 70 dB A from -75° azimuth. Please see Figure 2 for an illustration of the test setup.

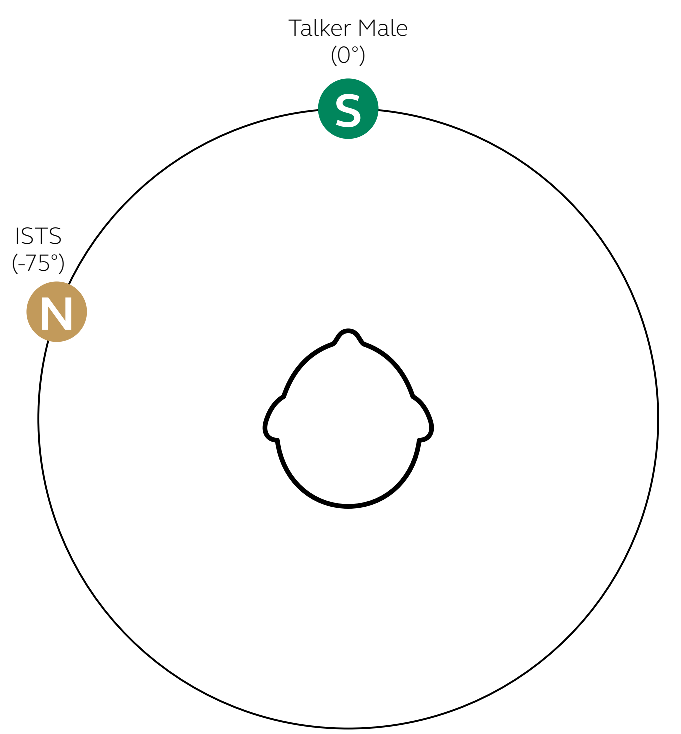

Figure 2. Illustration of test setup for the listening effort test.

Procedure

Participants attended two measurement sessions at Hörzentrum Oldenburg, each lasting approximately two hours. The first session started with a case history, otoscopy and audiogram. Based on the audiogram, the four pairs of hearing aids were fitted. Next, the individual parameters for CCOLSA were measured for aided conditions (ReSound Vivia devices), including SRTs for all three talkers (tested in interleaved order) against the babble noise and CCOLSA overlap times for 50% correct responses. For both measures, a training was performed before the actual measurements. Afterwards, the four hearing aids were tested in a counterbalanced, randomized order. One of these conditions was performed in session one, the other three were performed in session two. For each hearing aid condition, CCOLSA with selective attention and divided attention were tested first (randomized order), followed by ACALES.

Results and discussion

Speech recognition in noise results

Figure 3 shows the measured CCOLSA scores for the divided attention and the selective attention task. Scores were higher on the selective attention task than the divided attention task across the board. This reflects the greater difficulty of the divided attention task. For both tasks, the participants achieved the highest scores with the ReSound Vivia 9, although differences were not significant in all cases. Median scores for the divided attention task were 62.5% (ReSound Vivia), 54.2% (HA1), 51.7% (HA2), and 55.0% (HA3). For the selective-attention condition, the median scores are 72.5% (ReSound Vivia 9), 68.3% (HA1), 69.2% (HA2), and 70.1% (HA3).

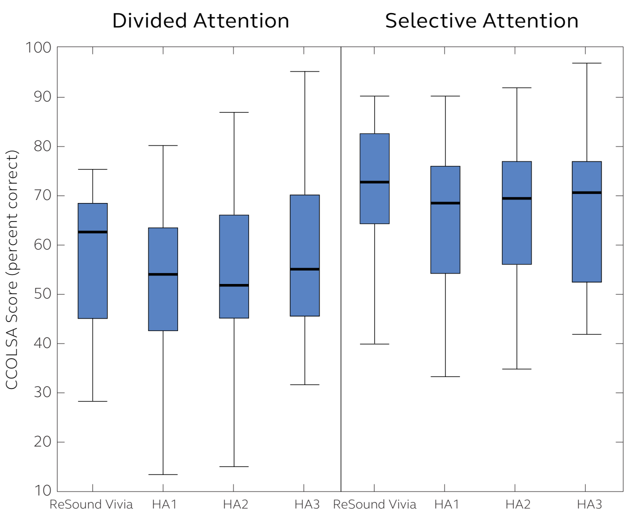

Figure 3. Measured CCOLSA scores for ReSound Vivia and the hearing aids from 3 other key brands (medians and interquartile ranges) are shown with results for the divided-attention task on the left and results for the selective-attention task to the right.

Figure 4 plots the benefit for ReSound Vivia 9 relative to that of each of the three hearing aids from other brands. Zero on this graph means that there is no difference in benefit between the other hearing aid and the ReSound Vivia 9. A positive result indicates that benefit was greater with the ReSound Vivia 9 than the other hearing aid. All data are normally distributed (Shapiro-Wilk test, $p>0.05$ for all conditions). For 5 of the 6 comparisons across the 3 hearing aids on both tasks, benefit was greater for the ReSound Vivia 9. For the selective attention condition, statistically significant average benefits of 6.3% points against HA1 ($p=0.0038$, T-test; Cohens d: 0.55) and 4.8% points against HA2 ($p=0.046$, T-test; Cohens d: 0.42) were found. The selective attention benefit for HA3 (mean: 3.7% points) and the benefits for the divided attention condition (means: 2.6% points for HA1, 2.8% points for HA2, and -1.4% points for HA3) were not significantly different from zero. For these comparisons, the equivalence of results (ReSound Vivia compared to each pair of hearing aids from other brands) was proven using TOST-tests ($p>0.05$ for all conditions).

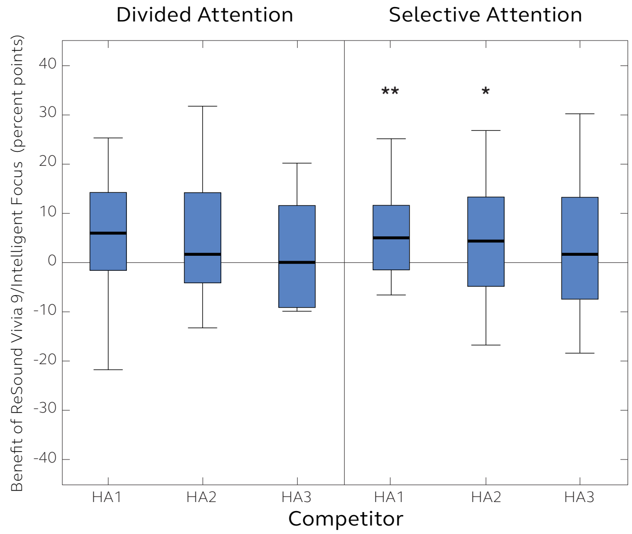

Figure 4. Benefit of the ReSound Vivia 9 compared to three hearing aids from other premium brands (medians and interquartile ranges). Results for the divided attention task are shown on the left while the selective attention task is shown on the right. Statistically significant differences from zero are indicated by asterisks. A positive difference indicates that greater benefit was observed with the ReSound Vivia 9 than the other hearing aid.

Intelligent Focus in the ReSound Vivia 9 meets or exceeds the industry benchmark for DNN-based features for speech recognition on an ecologically valid selective attention task and meets the industry benchmark for a divided attention speech recognition task. As mentioned previously, hearing aids have shared goals for using DNNs. These are that hearing aid users have a good listening experience in complex situations where they want to follow conversations. But the details of how the DNNs are applied differ. Only ReSound and one other brand currently use DNNs in the signal processing to achieve denoising. In this test the other brand was HA1, and the benefit of the ReSound solution was found to be significantly better. This means that ReSound denoising currently leads in terms of speech recognition in noise with selective attention and demonstrates strong performance that is better or equivalent to solutions that use DNNs to automatically control noise management feature.

Listening-effort results

Figure 5 shows the measured SNR for the rating categories "no effort", medium effort", and "extreme effort" for each hearing aid condition. For "no effort", median SNR of 7.5 dB (ReSound Vivia 9), 7.5 dB (HA1), 8.4 dB (HA2), and 7.4 dB (HA3) were measured. The category "medium effort" was rated at -1.4 dB (Vivia), -1.1 dB (HA1), -1.4 dB (HA2), and -1.5 dB (HA3) median SNR. "Extreme effort" was observed for median SNR of -8.7 dB (Vivia), -11.6 dB (HA1), -9.5 (HA2), and -11.4 dB (HA3). Statistically, the results for ReSound Vivia 9 are equivalent to the results of the other hearing aid brands (TOST-test, all $p>0.05$).

It is of interest to compare listening effort for speech levels occurring in everyday life. This is the region where the ACALES scale shows "medium effort" or a categorical rating of 7. In the current study, we measured medium effort at -1.4 dB SNR with the ReSound Vivia 9 with Intelligent Focus. For speech-in-speech, it has been reported that people with hearing loss who are unaided show medium listening effort on the ACALES at about +2dB SNR,11 whereas people with normal hearing rate medium listening effort at SNRs between -4 dB and 0 dB for comparable maskers.12 Clinical experience in testing people with hearing loss aided in similar speech-in-speech conditions has typically shown ratings of medium effort close to 0 dB SNR. Considering this, the subjective listening effort experienced by our participants for all hearing aids tested including the ReSound Vivia 9 occurred at a worse SNR than what we expected based on our clinical experience, at a much worse SNR than people with hearing loss listening unaided, and within the SNR range that has been reported for people with normal hearing. This supports that current hearing aids with DNN-driven features for noise management, including the ReSound Vivia 9 with Intelligent Focus, provide low listening effort that brings hearing aid users nearer the experience of people with normal hearing in moderately loud speech-in-speech environments.

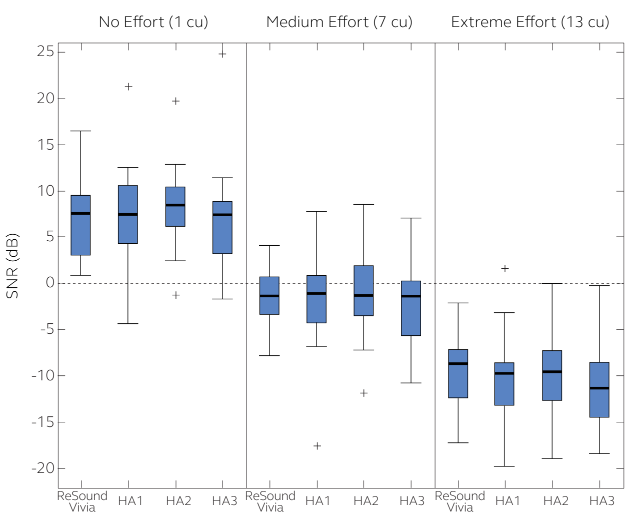

Figure 5. Measured ACALES results for the four hearing aid conditions (medians and interquartile ranges). The left panel shows SNR for the rating of "no effort", the middle panel shows SNR for "medium effort", and the right for "extreme effort".

Conclusions

- ReSound Vivia 9 with Intelligent Focus outperformed two of the hearing aids from other brands and was on-par with the third brand in terms of speech recognition in noise test on a selective attention task.
- The four hearing aid brands performed equally well in terms of listening effort on the ACALES test.

References

1. Schumacher J, Groth J. Intelligent Focus: How deep learning augments human intelligence. 2025.
2. Stender T, Castro K. An overview of DNN and its implementation in ReSound hearing aids. 2026.
3. Shinn-Cunningham BG, Ihlefeld A. Selective and Divided Attention: Extracting Information from Simultaneous Sound Sources. In Proceedings of ICAD 2004 Jul, Sydney.
4. Jespersen, CT, Dieu, Rubachandran, T. Organic Hearing drives user preference for Intelligent Focus. 2025.
5. Heeren, J., Nuesse, T., Latzel, M., Holube, I., Hohmann, V., Wagener, K. C., & Schulte, M. The Concurrent OLSA test: A method for speech recognition in multi-talker situations at fixed SNR. Trends in Hearing. 2022; 26, 23312165221108257.
6. Heeren, J., Hohmann, V., Schulte, M., & Wagener, K. C. Adaptive CCOLSA: Cognitive Overload Thresholds in a Multi-Talker Speech Test. In Forum Acusticum 2023.
7. Bisgaard N., Vlaming M.S.M.G., Dahlquist M. Standard audiograms for the IEC 60118-15 measurement procedure. Trends Amplfi. 2010 Jun;14(2):113-20. doi: 10.1177/1084713810379609.
8. Wagener, K.C., Kühnel, V., Kollmeier, B. Entwicklung und Evaluation eines Satz-tests in deutscher Sprache I: Design des Oldenburger Satztests. Z Audiol 1999;38 (1), 4-15.
9. Holube, I., Fredelake, S., Vlaming, M., Kollmeier, B. (2010). Development and analysis of an International Speech Test Signal (ISTS). Int J Audiol. 2010 Dec;49(12):891-903. doi: 10.3109/14992027.2010.506889.
10. Krueger, M., Schulte, M., Brand, T., Holube, I. Development of an adaptive scaling method for subjective listening effort. Journal of the Acoustical Society of America. 2017;141(6): 4680. doi: 10.1121/1.4986938.
11. Ibelings S, Schulte M, Krüger M, Holube I. Audiovisuelle Realisierung des subjektiven Höranstrengungsmessverfahrens ACALES. GMS Z Audiol (Audiol Acoust). 2020;2:Doc04.
12. Rennies J, Best V, Roverud E, Kidd Jr G. Energetic and informational components of speech-on-speech masking in binaural speech intelligibility and perceived listening effort. Trends in Hearing. 2019 Jun; 23, 2331216519854597.

Manufacturer According to FDA:

GN ReSound North America
5005 Dean Lakes Blvd.
Shakopee, MN 55379
USA
1-800-248-4327
pro.resound.com

ReSound Government Services
5005 Dean Lakes Blvd.
Shakopee, MN 55379
USA
1-800-392-9932
gs.resound.com

Manufacturer According to Health Cananda:

ReSound Canada
2 East Beaver Creek Road, Building 3
Richmond Hill, ON L4B 2N3
Canada
1-888-737-6863
pro.resound.com

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