ReSound GN

# Organic Hearing drives user preference for Intelligent Focus

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## Abstract

With ReSound Vivia™, we introduce a DNN-based noise reduction, Intelligent Noise Tracker. This combines with an upgraded 4-microphone binaural beamformer to form Intelligent Focus, our new default for the Hear in Noise program in premium hearing aids. This paper reports on three studies that quantified different aspects of Intelligent Noise Tracker and Intelligent Focus including listener preference compared to the legacy Front Focus feature, directional benefit of the upgraded beamforming, and efficiency of the DNN compared to another premium brand with DNN-based noise reduction.


Hearing in noise is an issue for people with hearing loss even when wearing hearing aids. The ReSound approach to supporting the ability to listen effectively in noisy environments builds on our Organic Hearing philosophy. This means that we seek to mimic natural hearing processes that enable the hearing aid user to use innate strategies to hear what they want in any environment. An example of how we apply this is the automatic "360 All-Around" program. Based on the acoustic environment, we apply technologies in a way that supports how people naturally tend to use their hearing in those scenes. Directionality is a particularly important technology in this scheme. ReSound uses a unique directional feature that applies strong 4-microphone binaural beamforming in the speech-important mid-frequencies, a 2-microphone fixed directional response in the high frequencies and omnidirectionality in the low frequencies. This approach provides impressive signal-to-noise ratio (SNR) improvement[1, 2] while preserving binaural hearing cues and ensuring seamless sound quality regardless of the active listening mode in 360 All-Around. The algorithm that controls listening modes uses straightforward rules and operates slowly to ensure smooth transitions.

Another important technology for more effective listening in noise is single-microphone noise reduction. Noise Tracker II is an example of this and is an integral part of both the 360 All-Around program, as well as the dedicated user-selectable program for hearing in challenging situations, called "Hear in Noise". Single-microphone noise reduction has the goal of separating speech and noise that are mixed; it is not dependent on the desired sound and the competing sound being spatially separated as is the case with directionality. The principle of single-microphone noise reduction is to reduce gain according to the spectrum of the noise while preserving speech audibility. Noise Tracker II can perform this quite well based on the assumption that noise backgrounds do not change as quickly as speech. It uses knowledge about speech acoustics – a model of speech - to identify the speech spectrum and assumes that the spectrum in pauses of speech is noise to be reduced. Unlike determining the best listening mode and when to apply directionality, calculating the gain reduction settings for Noise Tracker II is complex and must be done very quickly.

In real life environments, background noise is often dynamic and can quickly vary in level and frequency content. For example, dishes clattering, keys jangling, a dog barking, a few people bursting into laughter – all of these are everyday sounds found in hearing aid users' real surroundings and that may be bothersome to them. This means that the assumption of noise backgrounds being stable that is made in single-microphone noise reduction systems like Noise Tracker II are often not true. The risk is that the speech portion of a signal could be degraded in quality or made inaudible. We therefore considered whether deep learning, a type of artificial intelligence, might be able to provide a better method for calculating single-microphone noise reduction settings at a pace that could keep up with both speech and noise background dynamics. A deep neural network (DNN) was trained on many speech and noise samples to be able to recognise and separate the speech from the noise, and to calculate gain reduction settings that would affect only the noise. The goal of this data-driven single-microphone noise reduction system, called "Intelligent Noise Tracker" is to increase listening comfort with preserved sound quality. See Schumacher & Groth[3] for more details on Intelligent Noise Tracker.

#### Implementation in the Hear in Noise program

The manually selectable Hear in Noise program introduced in premium level technology combines Intelligent Noise Tracker with an upgraded 4-microphone binaural beamformer that extends the low frequency directional response to 250 Hz to maximise the potential for SNR benefit. A previous investigation of the effect of the Directional Mix setting (which defines the crossover frequency between directional and omnidirectional processing in the low frequencies) found that directional benefit for occluding fittings increased as the frequency area where directionality was applied was extended to lower frequencies.[4] Based on those results, the upgraded directional feature could be expected to provide 1 to 2 dB additional SNR improvement for people with occluding fittings. Minimal additional benefit might also be a result due to minor optimisation of the beamforming parameters relative to the legacy 4-microphone binaural beamformer used in the Front Focus feature.

The combination of the new 4-microphone binaural beamformer and the DNN-based noise reduction comprises the new Intelligent Focus feature which initially will be available in the microRIE form factor. Other styles will also offer the upgraded 4-microphone binaural beamformer, but with classic Noise Tracker II single-microphone noise reduction. This feature is called Clear Focus. Table 1 provides an overview of the directional response and single-microphone noise reduction system in Intelligent Focus, Clear Focus, and the legacy Front Focus.

**Table 1**

| | Noise reduction system | Directional response |
|---|---|---|
| **Intelligent Focus** | Intelligent Noise Tracker | Binaural beamforming 250-5000 Hz |
| **Clear Focus** | Noise Tracker II | Binaural beamforming 250-5000 Hz |
| **Front Focus** | Noise Tracker II | Binaural beamforming 550*-5000 Hz |

*for microRIE; the precise frequency depends on the hearing aid style

To learn how hearing aid users might benefit from the DNN-based noise reduction as well as the upgraded 4-microphone binaural beamformer, three studies were carried out. They focused on sound quality preferences, speech recognition in noise with both speech and noise in front, and efficiency of DNN based on speech recognition in noise with speech from changing locations.

## Study 1: Sound Quality Preference

### Methods

#### Participants

Twenty participants with bilateral mild-to-moderate sensorineural hearing loss participated in the test (13 male and 7 female). The test participants' median age was 78 years with a 1st quartile of 73 years and a 3rd quartile of 80 years. The test participants were experienced hearing aid users and current users of premium Receiver-in-the-Ear (RIE) hearing aids. The median years of experience with amplification was 14 years (1st quartile: 7 years and 3rd quartile: 20 years).

#### Hearing aids and fitting

A pair of rechargeable ReSound Vivia (VI960S-DRWC) RIE hearing aids were used for the sound quality experiment. The hearing aids were fitted with gain prescribed to an N3 audiogram[5] for experienced hearing aid users, using the proprietary Audiogram+ fitting rationale and power domes to optimise the hearing aid signal processing benefit. The hearing aids were fitted with four programs. One was the Hear in Noise program, while the other three were duplicates but with the following differences: Two of the four Hear in Noise programs were fitted with Intelligent Focus (see table 1). These two programs were fitted with two different levels of Intelligent Noise Tracker ("Considerable" and "Strong"). The two remaining Hear in Noise programs were fitted with the legacy feature Front Focus. These two programs were fitted with two different levels of Noise Tracker II ("Moderate" and "Strong").

#### Test conditions, material, and setup

ReSound and other hearing aid manufacturers have often carried out sound quality preference experiments by making recordings on an acoustic manikin and having test participants evaluate the conditions under headphones using the SenseLabOnline test system from FORCE Technology.[6, 7] The SenseLabOnline test system offers double blinding and eliminates multiple other sources of bias. The sound quality testing was conducted by having test participants do sound quality preference testing on the following pairs of conditions:

- Intelligent Focus ("considerable") versus Front Focus ("moderate")
- Intelligent Focus ("strong") versus Front Focus ("moderate")
- Intelligent Focus ("strong") versus Front Focus ("strong")

The testing order of the conditions was counterbalanced across participants. The participants repeated the paired comparisons while listening to multiple sound scenarios. A description of the sound scenarios is shown in Table 2. Except for the kitchen noise scene, which was recorded in an actual kitchen for the purpose of this test, the sound scenarios were selected from the ETSI noise database which is a public database containing various recordings of realistic background noises.[8] The sound scenes were supplemented with a concatenation of Dantale II and HINT female and male speech.

The recordings were binaural recordings made at ecologically valid SNRs to simulate real-life conversations. In real-life, conversations mostly happen at positive SNRs, because speakers adapt their vocal effort and distance to the listener when noise is present.[9-12] Hearing aid users typically do not expose themselves to conversations at negative SNRs, which are uncommon in the real world - also for people with normal hearing.[11-14] When testing for sound quality preference, it is desirable to present highly intelligible samples to keep participants engaged in the task.[14] As we were testing noise reduction systems, noise had to be present, but the SNRs needed to be high enough for the test participant to understand most speech comfortably. If the SNR is below 0 dB, the participant is likely to give up without expressing any preference.

**Table 2. The sound scenarios and SNRs were according to the table below:**

| Background noise | SPL(A) | SPL | SNR(A) |
|---|---|---|---|
| Cafeteria | 66 dB | 70 dB | 4 dB |
| Traffic | 70 dB | 74 dB | 4 dB |
| Voice distractor | 65 dB | 68 dB | 3 dB |
| Cafe | 70 dB | 75 dB | 5 dB |
| Car | 65 dB | 70 dB | 5 dB |
| Kitchen | 68 dB | 73 dB | 5 dB |

The six sound scenario recordings with the concatenated speech at the SNR(A)s listed in Table 2 were recorded with a Brüel & Kjær Type 4128 Head and Torso Simulator (HATS). The recordings were made for each sound scenario and test condition (each of the four hearing aid programs) while the test hearing aids (binaural recordings) were placed on the HATS' ear simulators.

When making the recordings, the audio source material was played for at least 60 seconds before the clips used for the test were recorded. This was done to give the hearing aids' adaptive algorithms time to adapt to each sound scenario.

The recordings were played back for the test participants over Beyerdynamic DT-990 Pro headphones. The stimuli were equalised to remove the influence of the HATS' ear canals and the headphone frequency response. The test participants were asked to adjust the playback level so that the Danish talker was at a comfortable level.

## Results/Discussion

### Intelligent Focus "Considerable" versus Front Focus "Moderate"

The preference of Intelligent Focus with "considerable" Intelligent Noise Tracker noise reduction versus Front Focus with "moderate" Noise Tracker II noise reduction in the Hear in Noise program is shown in Figure 1. The preference is shown for the five sound scenarios for which there was a statistically significant preference. A binomial statistical test was used to determine in which sound scenarios there were statistically significant differences. These were "Café" ($p<0.05$), "Car" ($p<0.001$), "Cafeteria" ($p<0.01$), "Voice distractor" ($p<0.001$) and "Traffic" ($p<0.05$). There was not a statistically significant difference for the "Kitchen" scenario ($p=0.12$).

The Hear in Noise program with Intelligent Focus was preferred over the Hear in Noise program with Front Focus in 87 of 100 trials while the Hear in Noise program with Front Focus only was preferred in 13 of 100 trials when summarising the preferences across background noises. Intelligent Focus with Intelligent Noise Tracker was thus preferred 87% of the time compared to legacy noise reduction.

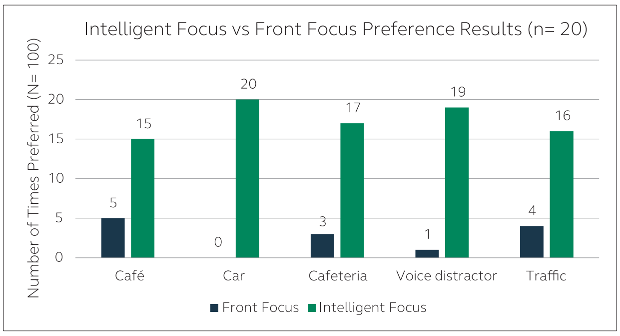


Figure 1. Preferences for Intelligent Focus compared to Front Focus for the 20 participants with mild-to-moderate hearing loss, and for the 5 sound scenarios for which there was a statistically significant preference.

### Intelligent Focus "Strong" versus Front Focus "Moderate"

The preference of Intelligent Focus with "strong" Intelligent Noise Tracker noise reduction compared to Front Focus with "moderate" Noise Tracker II noise reduction in the Hear in Noise program is shown in Figure 2. A binomial statistical test was used to determine whether the differences in preference were statistically significant differences. There was a statistically significant preference for Intelligent Focus for all six sound scenarios, including "Café" ($p<0.001$), "Car" ($p<0.001$), "Kitchen" ($p<0.01$), "Cafeteria" ($p<0.05$), "Voice distractor" ($p<.001$), and "Traffic" ($p<0.01$). When the preferences are combined across background noises, Intelligent Focus with Intelligent Noise Tracker was preferred 89% of the time compared to legacy noise reduction.

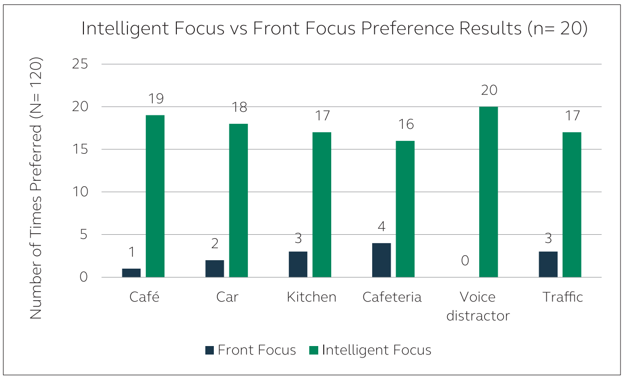


Figure 2. Preference for Intelligent Focus compared to Front Focus for the 20 participants with mild-to-moderate hearing loss and for all 6 sound scenarios as there was a statistically significant preference in all sounds.

### Intelligent Focus "Strong" versus Front Focus "Strong"

The preference of Intelligent Focus with "strong" noise reduction compared to Front Focus with "strong" noise reduction in the Hear in Noise program is shown in Figure 3. The preference is shown for the four sound scenarios for which there was a statistically significant preference.

A binomial statistical test was used to determine in which sound scenarios there were statistically significant differences. These were “Café” ($p<0.001$), “Car” ($p<0.05$), “Cafeteria” ($p<0.001$) and “Voice distractor” ($p<0.001$). There was not a statistically significant difference for the “Kitchen” ($p=0.26$) and “Traffic” ($p=1.00$) scenarios.

The Hear in Noise program with Intelligent Focus was preferred over the Hear in Noise program with Front Focus 71 of the times while the Hear in Noise program with Front Focus only was preferred 9 times when summarising the preferences across background noises. Intelligent Focus with Intelligent Noise Tracker is preferred 89% of the time compared to legacy noise reduction.

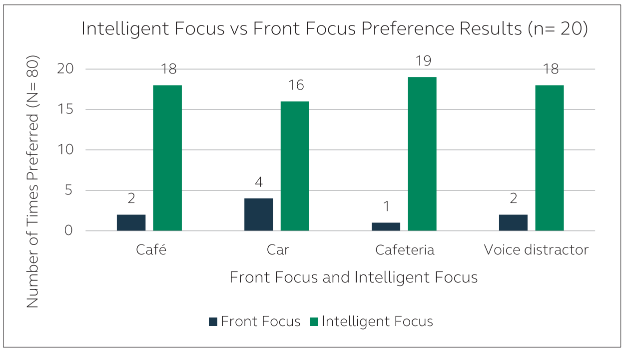


Figure 3. Preferences for Intelligent Focus compared to Front Focus both with a strong level of noise reduction for the 20 participants with mild-to-moderate hearing loss and for four of the sounds for which there was a statistically significant preference.

## Study 2: Speech Intelligibility in Noise

### Methods

#### Participants

Eighteen of the twenty participants that participated in the sound quality preference test also participated in a speech intelligibility in noise test in an optimised 4-microphone beamformer test setup.

#### Hearing aids, fitting and test conditions

ReSound Vivia RIE hearing aids were fitted binaurally with power domes to optimise the 4-microphone binaural beamformer and noise reduction benefit. The hearing aids were fitted to the test participants’ individual hearing loss and experience with amplification based on the proprietary fitting rationale Audiogram+. The hearing aids were fitted with the following hearing aid programs:

- Program 1: Hear in Noise program with legacy Front Focus
- Program 2: Hear in Noise program with Clear Focus
- Program 3: Hear in Noise program with omnidirectional processing instead of 4-microphone beamforming

In addition, premium RIE hearing aids from another leading brand were tested. They were also fitted with power domes to optimise the 4-microphone beamformer and noise reduction benefit. The hearing aids were fitted to the participants’ individual hearing loss and experience with amplification based on the manufacturer’s default fitting rationale. The hearing aids were fitted with a dedicated program for hearing in noise with 4-microphone beamforming as well as a copy of this program with omnidirectional processing instead of 4-microphone beamforming.

#### Test material

The participants completed a speech intelligibility in noise test that is a slightly modified version of the Dantale II test.[15] The test is comprised of 5-word sentences and was presented in a background of static speech-shaped noise at 65 dB SPL. Thirty sentences were administered for each test. The level of the speech was manipulated to determine a speech reception threshold (SRT) of 50% correct performance, resulting in a dB SNR score, with better performance revealed through lower dB SNR scores. The hearing aids tested have adaptive features that rely on identification of speech and noise in the environment. To ensure that all adaptive features were activated during testing, the Dantale II test noise was started 60 seconds before testing was initiated. The test was conducted in an idealised situation to maximise possible benefit from the directional features.

#### Test setup

Testing was completed with the participants seated in a sound booth with speech presented at 0 degrees azimuth, and static noise presented at 75 degrees azimuth to the right. The positioning of the competing noise in the front plane was intended to highlight the stronger directional response - which can also be thought of in terms of a narrower directional beam. The setup is illustrated in Figure 4. The testing order of conditions and the sentence lists were counterbalanced across participants.

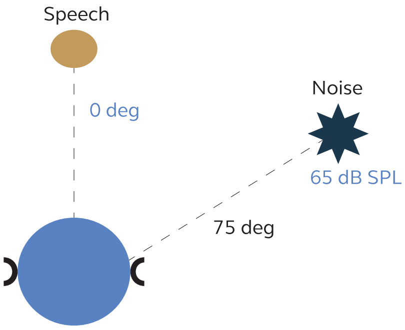


Figure 4. Test setup used for measuring SRTs with adaptive SNRs for a front talker in omnidirectional-, Front Focus- and Intelligent Focus mode.

The Dantale II speech and noise material was band-pass filtered from 550-4000 Hz to increase task difficulty and avoid ceiling effects in this test setup. The bandpass filtering was performed in Adobe Audition using the FFT filter plugin, with as steep as possible ramp-up and ramp-down of the filter.

## Results/Discussion

No significant differences were observed between Clear Focus and Front Focus on a group level. This result was unsurprising as the test setup with the band-filtered speech and noise was expected to underestimate the added benefit of Clear Focus; the primary difference between Clear Focus and the legacy Front Focus is the low frequency directionality response. Even so, 61% (11 of the 18) test participants performed better on the speech intelligibility test in noise with Clear Focus in the Hear in Noise program than they did with legacy Front Focus in the Hear in Noise program. This may reflect the small optimisations made in the beamforming that could have affected benefit for individuals if not on average.

When comparing directional benefit with Clear Focus to 4-microphone beamforming in another premium brand on this test, both provided significant mean benefit compared to omnidirectional (Table 3). Compared to the other brand, the directional benefit provided by Clear Focus was significantly better (p<.01) as shown in Figure 5. A 2024 study showed similar directional benefit with a previous product from the same brand (Table 3). Both Clear Focus and Front Focus provided a directional benefit greater than that provided by the 4-microphone binaural beamforming in the other brand. In addition, 83% (15 of 18 test participants) showed better speech recognition in noise performance with Clear Focus than with the 4-microphone beamforming from the other premium brand.

**Table 3.**

| | ReSound Vivia Clear Focus | ReSound Nexia Front Focus | Brand A 4-mic beamforming (2025 hearing aid) | Brand A 4-mic beamforming (2024 hearing aid)* |
|---|---|---|---|---|
| **Directional benefit** | 7.6 dB (p<.001) | 7.0 dB (p<.001) | 4.9 dB (p<.001) | 4.0 dB (p<.001) |

*Jespersen et al (2024)[2]

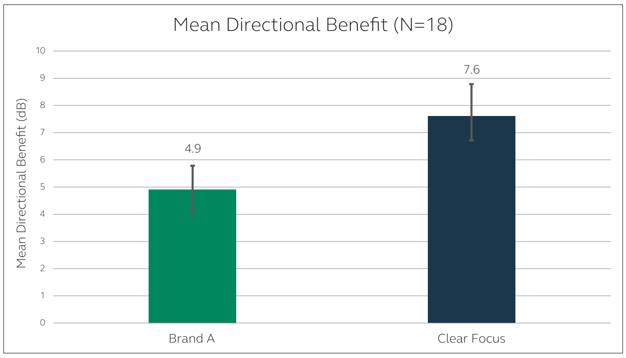


Figure 5. Test participants' mean directional benefit with ReSound's Clear Focus and another premium brand's 4-microphone binaural beamforming. Error bars show 95% confidence intervals.

## Study 3: Efficiency of DNN-based noise reduction

### Methods

**Participants**
Fourteen of the twenty participants that participated in the sound quality preference test also participated in a speech intelligibility in noise test that is more representative of a real-world situation than typical speech-in-noise tests. This test has competing single talkers, and the target talker randomly is presented from in front of and behind the listener which makes the task quite difficult. This test also allows assessment of accessibility of off-axis sound that might be of interest to the listener.

**Hearing aids, fitting and test conditions**
ReSound Vivia RIE hearing aids were fitted binaurally with power domes to optimize the 4-microphone binaural beamformer and noise reduction benefit. The hearing aids were fitted to the test participants' individual hearing losses and experience with amplification based on the proprietary fitting rationale Audiogram+. The hearing aids were fitted with the following hearing aid programs:
- Program 1: Hear in Noise program with Intelligent Focus.
- Program 2: Hear in Noise program with Clear Focus.

Premium RIE hearing aids from another leading brand were fitted binaurally with power domes to optimize the directional and noise reduction benefit. The hearing aids were fitted to the test participants' individual hearing loss and experience with amplification based on the brand's default fitting rationale. The hearing aids were fitted with the following hearing aid programs:
- Program 1: Dedicated program for hearing in noise with directionality and DNN-based noise reduction.
- Program 2: Dedicated program for hearing in noise with directionality and no noise reduction.

**Test material**
The test participants completed an adaptive speech intelligibility listening test, hereafter referred to as the "DAT" test.[16] This test yields the SNR at the speech reception threshold (SRT). In this test, both the signal and the competing noise are individual talkers, which is exceptionally challenging compared to speech-shaped noise or babble, as there is informational as well as energetic masking taking place. The target talker sentences were played at 65 dB SPL, and the presentation level of the competing talkers was varied adaptively in 2 dB steps beginning at 55 dB SPL. Four conditions were completed in which the target sentences came from either the front or back loudspeaker as illustrated in Figure 6. The sequence of the conditions was counterbalanced among test participants. The masker talkers were played from the remaining two loudspeakers.

The programs tested in each brand's hearing aids have adaptive features that rely on identification of speech and noise in the environment. Therefore, an attempt was made to ensure that adaptive features will engage. In addition to the DAT corpus, speech-shaped noise from the Dantale II test[16] was played at a level of 45 dB SPL. The speech-shaped noise was played from loudspeakers directly to the left, directly behind, and directly to the right of the test participant. Furthermore, the ISTS signal was played at 65 dB SPL from the front loudspeaker throughout the duration of the test except while the target and masker sentences were played. For each test condition, the ISTS signal and the Dantale II test noise were started thirty seconds before the first test to activate any adaptive settings in the hearing aids.

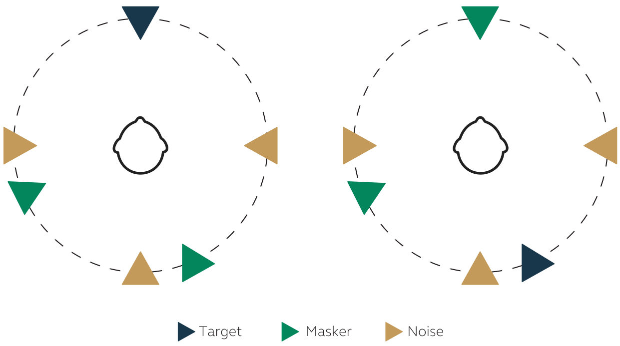


Figure 6. In the DAT test setup, target speech was presented either from the front or the back, with single talker maskers presented simultaneously from the side and either the front or back. Low level speech-shaped noise was also presented in the rear hemifield.

The test participants completed the two test setup conditions for each of the four test conditions. The sequence of the conditions was randomised for the test participants. Each test participant completed three training lists prior to beginning data collection.

## Results/Discussion

The mean benefit of Intelligent Focus was -5.4 dB while the mean benefit of the other brand's program for hearing in noise with directionality and DNN-based noise reduction was -2.7 dB. While this advantage for Intelligent Focus was not significant at a group level, 9 of the 14 (64%) test participants obtained better results with Intelligent Focus.

One purpose of carrying out this test was to estimate the effect of the DNN-based noise reduction. The DAT test was chosen due to its difficulty and the fact that both target speech and maskers occur both from the front and from the back, and that speech can be both a target and a masker. It has been established that full bandwidth 4-microphone binaural beamforming can work against audibility when target speech is in back.[17] It is also of interest to know whether the DNN-based noise reduction might make matters better or worse. By subtracting the test condition without DNN-based noise reduction from the condition with DNN-based noise reduction, it is possible to isolate the effect of this feature. Due to limitations in programming the ReSound hearing aids, the benefit of the Intelligent Noise Tracker (the DNN-based noise reduction) is compared to legacy Noise Tracker II while the comparison for the other brand is for the feature on versus off. This means that the benefit for ReSound compared to the other brand may be underestimated. The benefit for target speech in front and in back were averaged. The average benefit of Intelligent Noise Tracker compared to Noise Tracker II was .6 dB while the benefit of the DNN-based noise reduction for the other brand was 1.1 dB. This difference is insignificant and so small that the benefit can be considered equivalent.

As discussed in Schumacher & Groth[3] the DNN chip in the ReSound Vivia hearing aids was scaled to optimise the relationship between hearing aid capabilities, size of the chip, and power consumption. By comparing the benefit of the DNN-based noise reduction systems in the two brands of hearing aids in relation to the reported size of their DNNs, it is possible to quantify the efficiency of one versus the other. This can be accomplished by computing the ratio of the benefit per node of each DNN. Since no significant difference in benefit per brand was shown, the efficiency is simply the ratio of the difference in size in the two DNNs. The ReSound DNN has 17 times fewer nodes than the DNN of the other brand. This means that the DNN is 17 times more efficient, or that each node works 17 times harder in the ReSound system. The advantage of this efficiency is that users receive equivalent benefit, but in a device that can be physically smaller and use less battery.

## Conclusion

We carried out three studies to illustrate different aspects of the Intelligent Focus feature and conclude:

- Listeners show a strong preference for Intelligent Focus compared to legacy Front Focus in a variety of noise backgrounds.
- Directional performance of the upgraded 4-microphone binaural beamformer is equivalent to the legacy system when tested with band-filtered speech and noise, both presented in the front hemifield. Most individuals showed better performance with the new technology.
- Directional benefit of the upgraded 4-microphone binaural beamformer is significantly better than the benefit provided by another premium brand's 4-microphone binaural beamformer.
- The ReSound DNN is 17 times more efficient than the DNN of another premium brand.

## References


1. Jespersen CT, Groth, J. Enhanced directional strategy with new binaural beamformer leads to vastly improved speech recognition in noise. ReSound white paper. 2022.

2. Jespersen CT, Kirkwood BC, Reimers S, Groth J. Industry best speech recognition when both speech and noise are in front. ReSound white paper. 2024.

3. Schumacher J, Groth J. Intelligent Focus: How deep learning augments human intelligence. ReSound white paper. 2025.

4. Møller K, Jespersen C. The effect of bandsplit directionality on speech recognition and noise perception. Hearing Review. 2013. Jun;20(5):17-24.

5. Bisgaard N, Vlaming MS, Dahlquist M. Standard audiograms for the IEC 60118-15 measurement procedure. Trends Amplif. 2010;14:113-120.

6. Legarth SV, Simonsen CS, Dyrlund O, Bramsloew L, Jespersen C. Establishing and qualifying a hearing impaired expert listening panel. Poster presentation at: IHCON; 2012; Lake Tahoe, Calif.

7. Jespersen CT. Independent study identifies a method for evaluating hearing instrument sound quality. Hearing Review. 2014;21(03):36-40.

8. Directory Listing /stq/Open/EG 202 396-1 Background noise database/Binaural_Signals (etsi.org)

9. Bottalico P, Passione II, Graetzer S, Hunter EJ. Evaluation of the starting point of the Lombard effect. Acta Acustica United With Acustica. 2017 Jan 1;103(1):169-72.

10. Smeds, Karolina; Wolters, F; and Rung, M. Estimation of signal-to-noise ratios in realistic sound scenarios. Journal of the American Academy of Audiology 26.02 (2015): 183-196

11. Wagener, KC; Hansen, M; and Ludvigsen, C. Recording and classification of the acoustic environment of hearing aid users. Journal of the American Academy of Audiology 19.04 (2008): 348-370.

12. Weisser, A and Jörg Buchholz, JM. Conversational speech levels and signal-to-noise ratios in realistic acoustic conditions. The Journal of the Acoustical Society of America 145.1 (2019): 349-360.

13. Wu, YH. et al. Characteristics of real-world signal to noise ratios and speech listening situations of older adults with mild to moderate hearing loss. Ear & Hearing 39.2 (2018): 293-304.

14. Brons I, Houben R, Dreschler WA. Effects of Noise Reduction on Speech Intelligibility, Perceived Listening Effort, and Personal Preference in Hearing-Impaired Listeners. Trends in Hearing. 2014;18.

15. Wagener K, Josvassen JL, Ardenkjær R. (2003) Design, optimization, and evaluation of a Danish sentence test in noise. International Journal of Audiology, 42: 10-17.

16. Neher T. A Danish open-set speech corpus for competing-speech studies. The Journal of the Acoustical Society of America. 2014; 135(1):407-420

17. Groth J, Kirkwood B, Cui T, Hougaard O, Dieu L. Empowering hearing aid users with directional technology designed for the real world. ReSound white paper. 2023.

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