

The Benefits of Balancing Comfort and Intelligibility: Environmental Optimizer™ II

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Abstract

Dynamic listening environments encountered throughout the day present a difficult communication challenge for hearing aid end-users. The challenge is to balance comfort in noise and speech intelligibility across shifting combinations of quiet and noisy environments. The Environmental Optimizer™ II (EO II) by ReSound is designed to specifically address this challenge. The following paper provides an overview of this feature. Research conducted at the University of Giessen demonstrated a trend in patient preference for a device that utilizes the EO II feature. The experiment and results will be discussed.

As a basic amplifier, a hearing aid can easily increase the sound pressure level for speech and other environmental sounds. However, the limits in the dynamic capacity of a basic amplifier to strike a balance between comfort and intelligibility are quickly revealed when experienced across several varied sound environments.

Processing, such as wide dynamic range compression (WDRC), has vastly improved comfort and sound quality by making soft sounds audible without over amplifying high input level sounds, and avoiding distortion due to peak clipping. Manual volume controls have allowed end-users to make adjustments to the overall volume based upon their preferences in a given situation. Even with these improvements, WDRC may provide more gain than desired in some situations. Patients often may not understand when or how to operate their volume control, or lack the manual dexterity to accurately manipulate the control.

The Environmental Optimizer™ II (EO II) is designed to achieve the balance between comfort and intelligibility by maintaining the gain characteristics prescribed by WDRC while automatically altering the volume in a manner based on end user behavior. Additionally, noise reduction is adjusted per environment to provide a more finely tuned listening experience for patients.

The EO II feature uses three fundamental components to maintain a balance between comfort and intelligibility across changing environments; 1) environmental classification 2) volume control changes and 3) noise reduction adjustments. The analysis of the sound

environment begins with two basic measurements of dB SPL and a signal-to-noise ratio (SNR) estimation. The analysis of these two measurements allows the hearing aid processor to categorize the surroundings into one of seven environments. These seven environments are labeled “quiet”, “soft speech”, “loud speech”, “speech in noise moderate”, “speech in noise loud”, “noise moderate” and “noise loud”. If the listening situation can be categorized in more than one environment, it will be classified in more than one environment as well.

Once categorized, the EO II feature automatically increases or decreases gain settings. For example, if speech in noise is identified, and the preferred level for this situation is 2 dB less than prescribed gain for the hearing loss, the EO II feature will reduce the overall gain in this environment by 2 dB. When the environmental characteristics change, or the patient moves into a different sound environment, perhaps one that is quiet with a single talker, the overall volume will change to the level specified for that condition. Furthermore, different levels of noise reduction may also be desired per environment.

Difficulty “hearing in noise” continues to be a significant source of hearing instrument rejection. The breakdown that occurs when listening in noise is often related to two components: 1) poor signal-to-noise ratio, and 2) the noisy environment is uncomfortably loud and thus very distracting. Separate but overlapping solutions have been designed to address these two components.

Directional microphone technology is the primary method for improving the signal-to-noise ratio and digital noise reduction can improve hearing comfort and sound quality. In order to balance comfort and intelligibility, the Environmental Optimizer™ II can be used in conjunction with any of ReSound's directional options. These directional options will help ensure that the SNR is optimized in a noisy environment. The integrated automated adjustments of volume and noise reduction (NoiseTracker™ II) will assist patients who experience discomfort in the presence of background noise.

Noise reduction algorithms typically function by sampling the incoming signal and identifying noise or speech based upon the modulation characteristics. Simply put, the assumption used in most algorithms is that speech typically exhibits high modulation while noise modulates less. After the algorithm has analyzed the input signal, processing is applied whereby band specific gain reduction is applied. Notably, not all noise reduction strategies are able to accurately identify speech in noise. Some approaches to noise reduction systems have been shown to erroneously apply gain reduction. Figure 1 shows how two different modulation-based noise reduction systems affect steady-state noise and speech embedded in this noise. While both systems reduce the noise level to some degree compared to the original signal, the level and peaks of the speech signal are also reduced. This strategy could conceivably reduce gain of important speech information resulting in reduced audibility or muffled sound quality. For that reason, a precise noise reduction method which suppresses noise specifically in frequency regions where signal-to-noise ratio is low is superior.



Figure 1. Modulation-based noise reduction systems can decrease noise levels, but can also affect gain for speech. Waveforms recorded with two different systems show reduction of peaks of speech, which could impact both speech clarity and audibility.

Over the years, most noise reductions systems have been implemented in such a way that the processing

is fixed across listening environments in either an On/Off paradigm or a “degree of noise reduction” setting (mild, moderate, strong etc.) Different levels of noise reduction could be assigned to manually selectable programs intended for use in particular situations in a multi-program device. While this strategy might be agreeable for some, this requires the end user to know when and how to use the individual programs. Given that constant noise reduction settings might have a negative impact on either speech intelligibility or comfort depending on the environment, the idea of adjustable noise reduction, in a manner similar to a volume control, was explored.

In an internal trial, subjects were asked to manually adjust the noise reduction in environments that differed in input sound pressure level and SNR. Figure 2 illustrates that in environments of high levels and low signal-to-noise ratio, patients preferred to have noise reduction set at a high level. Conversely, when the environment had a softer overall level and a SNR estimate, less noise reduction was preferred.

Even though the goal of noise reduction is to reduce background noise without impacting the speech signal, the level of noise reduction can alter the attack time and the amount of per band gain reduction associated with noise reduction. For this reason, environmentally based noise reduction has very clear advantages. Specific settings can be implemented without the need to adjust any manual control like a push button. Improved hearing in multiple environments can occur with much reduced listening effort.

In addition to the per environment automated adjustments of NoiseTracker™ II, the EO II feature has been updated to use a more refined strategy for environmental classification. In many cases, the environment does not clearly fall into one of the system's seven defined categories. For example, during a family dinner at home, the classified environment will change as conversations ebb and flow, and background noises from music or TV, or clearing the table intrude.

The algorithm steers the volume and NoiseTracker™ II settings to a continuously changing linear combination of the prescribed settings for the three most probable categories (Figure 3). Because of the hearing

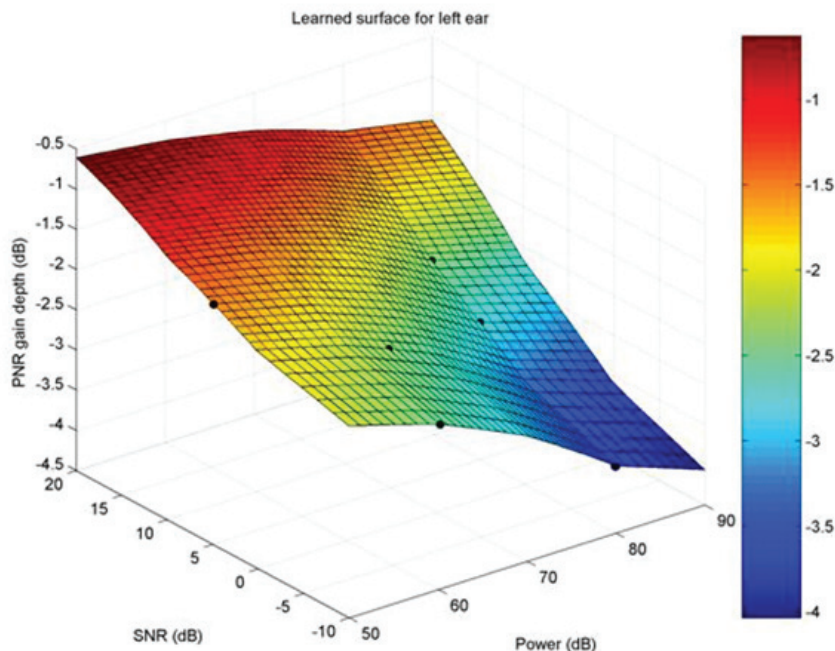


Figure 2: Example of results from an internal trial where subjects were asked to adjust the noise reduction in environments that differed in input sound pressure level and SNR. In environments of high levels and low signal-to-noise ratio, patients preferred to have noise reduction set at a high level. Conversely, when the environment had a softer overall level and a SNR estimate, less noise reduction was preferred.

aid’s constant ability to access combinations of classifications, gradual behind-the-scenes changes to the hearing instrument function allow for the wearer to experience transparent sound transitions.

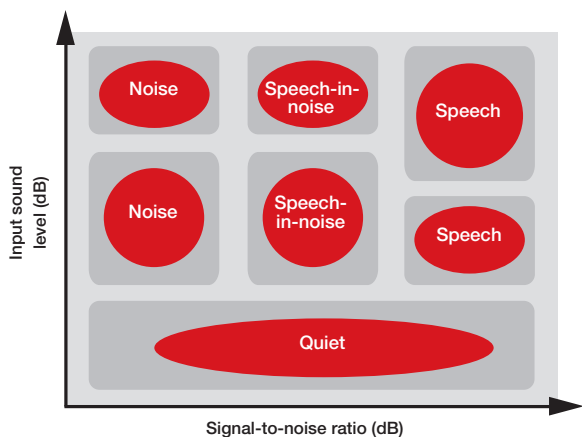


Figure 3: The categorization of environments by input level and SNR estimation is continuous. The algorithm steers the volume and Noisetracker II settings to a continuously changing linear combination of the prescribed settings for the three most probable categories.

As part of a study investigating benefit of the EO II feature, ten experienced hearing instrument users wore Alera 960 receiver-in-the-ear (RIE) devices during two week-long trial periods. During one period, the EO II feature was activated at the prescribed settings,

and during the other period, the EO II feature was not activated. Gain settings were kept constant for the two trial periods, and the conditions were counterbalanced.

The Hearing Aid Satisfaction Scale (HASS) was administered following each trial period to assess the impact of the EO II feature.¹ Figure 4 shows the median satisfaction ratings for features and listening situations where the EO II might be expected to offer benefit beyond the basic hearing instrument processing.

Consistent with expectations, differences between the two conditions were subtle. The participants’ satisfaction when the EO II was on was slightly higher for situations like one-to-one conversations, at restaurants and when in a car. Overall, there was a small but significantly higher satisfaction rating with EO II on as compared to off ($p=.002$).

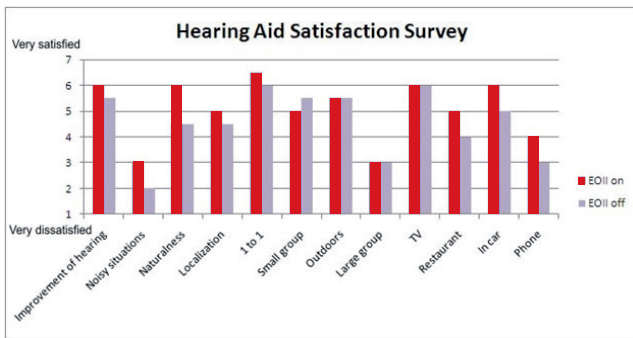


Figure 4: Median satisfaction ratings for the Environmental Optimizer™ II on and off conditions.

Overall hearing aid satisfaction has been correlated to a hearing aid's ability to provide improved hearing in multiple listening environments (MLE).² This concept is of paramount importance considering that the hearing instruments are intended for continual wear throughout the day.

A hearing instrument fitting typically begins with a prescriptive setting for compression characteristics based on individual audiometric data. These singular gain and parameter settings typically do not meet the listening needs in all conditions. Throughout the day, end-users might want to enhance or diminish different aspects of the amplified sound in different situations. The Environmental Optimizer™ II enhances satisfaction by seamlessly adapting volume and noise reduction to the most advantageous settings for each listening environment encountered by the wearer.

SUMMARY

In the single-blinded, randomized study previously described, patient preference for the Environmental Optimization™ II has been demonstrated.

It should be noted that other noise abating strategies such as directional microphones were not used to ensure that the only the effects of the environmental optimizer were used. Given these results, the EO II feature can satisfy users' preferences in their dynamic listening environments by providing automatic, personalized volume control. Many of the negative and impractical issues related to frequent or necessary manipulation of a manual volume control or program switch have been removed. Automated volume control functionality is combined with individually tailored adaptive noise reduction to adapt gain for both multiple listening environments and comfort in noise.

The EO II feature, through automated adjustments of both gain and NoiseTracker™ II settings, can improve hearing instrument utility across listening environments and provide a more satisfactory listening experience.

REFERENCES

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