

inconspicuousness of an otherwise cosmetically discreet instrument. Moreover, volume controls are often not available on popular, small devices such as CICs and mini-BTEs. Manual manipulation of the volume control can be difficult for individuals with poor dexterity.

NOISE REDUCTION FOR LISTENING COMFORT

Difficulty hearing in noise and discomfort in noise continue to be significant sources of hearing instrument rejection. Although directional microphone technology has been the primary method for improving the signal-to-noise ratio, digital noise reduction strategies can be implemented to improve hearing comfort and sound quality. Noise reduction is advantageous in both single and dual microphone instruments. This feature can assist in acceptance of amplification for users who neglect to access their directional microphone settings in noise or do not have automatic, adaptive microphone technology. Furthermore, directional microphones improve signal-to-noise ratios based on position of signal of interest where digital noise reduction algorithms are beneficial when the signal is embedded in noise.

Notably, not all noise reduction strategies are able to accurately identify speech in noise. Modulation-based approaches to noise reduction systems have been shown to erroneously apply gain reduction. Figure 1

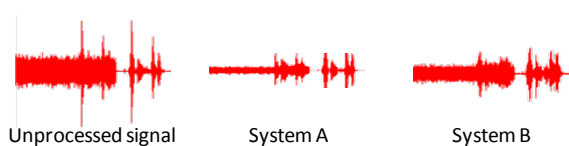


Figure 1. Modulation-based noise reduction systems can decrease noise levels, but can also affect gain for speech. Waveforms recorded with two different systems show reduction of peaks of speech, which could impact both speech clarity and audibility.

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.

ENVIRONMENTAL OPTIMIZER II

An automatic, personalized volume control solves some of the negative and impractical issues related to frequent or necessary manipulation to a manual volume control or program switch. This option combined with individually tailored, accurate, adaptive noise reduction is an extraordinary solution to the complaints of hearing instrument users—both the need to adapt to multiple listening environments and comfort in noise are addressed. Environmental Optimizer II automatically increases or decreases gain and/or NoiseTracker II settings when the hearing instrument identifies a change to the listening environment. For instance, if speech in noise is identified, and the preferred level for this situation is 2 dB less than prescribed gain for other listening environments, one could set the Environmental Optimizer II to reduce gain in this environment without affecting aided benefit for other listening situations. Further, if noise reduction is also desired, overall gain is not additionally reduced- the speech signal level is maintained and only non-speech sounds are reduced. The advantage of environmentally based gain and noise reduction fine-tuning is apparent; very specific settings can be implemented without the need to compromise. Improved hearing in multiple environments can occur with much reduced listening effort.

The Environmental Optimizer II allows for seamless changes to hearing instrument function in order for the user to adapt to the many listening situations one could potentially encounter. Clinical experience with environmentally dependent changes in volume has revealed that wearers prefer changes in hearing instrument settings to be small and gradual for acoustically similar environments. For example, the acoustic

environment during a dinner at home with friends may shift from low-level speech to speech-in-noise and even to noise with the ebb and flow of conversation and laughter. In this situation, large, quick changes in hearing instrument settings may be perceived as drastic and distracting to the wearer.

The classification system that steers the hearing instrument settings categorizes the acoustic surroundings into a scheme of seven environments as indicated by the darker ovals in Figure 2. Classification is probability-based and depends on the signal-to-noise ratio and sound level. In many real-world situations, the acoustic environment often falls between categories or shifts among closely related environments. An improvement in this classification system is that it takes these frequently occurring situations into account by assigning combinations of environments to the most probably candidates. Likewise, the Environmental Optimizer II settings applied will be linear combinations of the settings for the most probable environments. This results in gradual behind-the-scenes changes, allowing the wearer to always experience

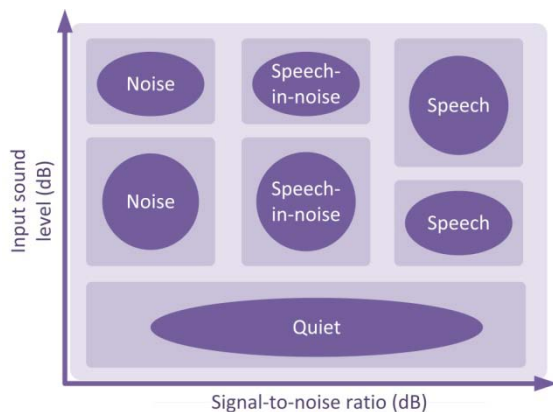


Figure 2. Acoustic environments are classified according to the estimated speech-to-noise ratio and the overall sound level. To prevent abrupt changes in hearing instrument settings in dynamic situations, combinations of intermediate volume and NoiseTracker II settings are continuously recalculated.

transparent and comfortable sound transitions.

In-house research trials involving both normal-hearing and hearing-impaired participants revealed that environmentally

dependent changes in volume and NoiseTracker II settings were positively judged when acoustic environments varied. In these trials, participants listened in dynamic acoustic environments with hearing instruments programmed in 3 ways: 1) with constant gain and noise reduction settings, 2) with environmentally dependent gain settings only, and 3) with both environmentally dependent gain and noise reduction settings. Both conditions with the environmentally dependent settings were preferred over the condition with the constant settings.

Similarly, Zakis and colleagues⁶ investigated the preferences, speech understanding and satisfaction with four different configurations of environmentally dependent noise reduction. Their results indicated all subjects preferred a configuration where noise reduction varied based on input noise level in comparison to constant noise reduction configurations that reduced the same amount of gain regardless of the incoming sound characteristics. Based on the outcomes of their study, the investigators postulated “highly configurable environmental noise reduction may provide higher levels of satisfaction for hearing-aid users by allowing for differences between individual needs and preferences”.

NOISETRACKER II

The success of the Environmental Optimizer II depends greatly on the ability of NoiseTracker II to reduce noise in varying acoustic environments. NoiseTracker II can uniquely target undesirable background noise even in challenging environments where both speech and competing speech babble are present. As its name implies, NoiseTracker II identifies and tracks both speech and noise, and limits gain reduction to frequency regions and points in time where the signal-to-noise ratio is low.

Based on spectral subtraction, NoiseTracker II uses an accurate method of speech detection and can thus limit analysis of the noise spectrum to pauses in the speech. By comparing the speech and noise analyses, the algorithm can continually update a band-

dependent signal-to-noise ratio which feeds into a gain reduction function. The amount of gain reduction varies according to the level set by the clinician during the fitting and has traditionally been set based on expectations to the hearing instrument wearer’s primary listening environments.

Figure 3 shows a speech signal embedded in a background of speech babble, which is the most challenging acoustic environment for a noise reduction system. Less sophisticated noise reduction systems, such as those based on modulation, will fail to accurately capture the speech information in such a background and will tend to reduce amplification for both the desired speech and the competing noise. In contrast, NoiseTracker II can reduce the noise without affecting the speech, making listening easier and more comfortable.

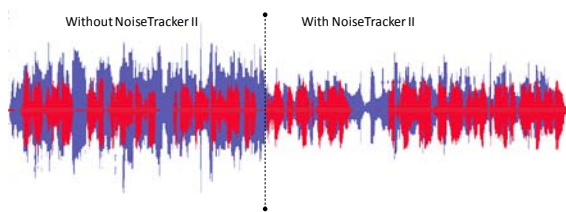


Figure 4. A waveform with speech (red) in a speech babble background (blue). When NoiseTracker II is active, the level of the noise is reduced without impacting the speech signal.

SETTING THE ENVIRONMENTAL OPTIMIZER II

The Aventa3 fitting software applies default Environmental Optimizer II settings based on individual hearing loss in addition to evidence obtained from study of a volume control use in various listening environments⁷. The study completed at the Oldenberg University research facility in Germany documented hearing impaired subjects’ preferred increased volume in quiet and when speech was present. A decrease in volume was favored in the presence of noise. The default settings reflect these preferences and are conservative in nature.

The Environmental Optimizer II can be customized by the fitter using the sliding controls to meet the specific needs of the user. The personal volume settings for each

of the seven listening environments are displayed in the Environmental Optimizer II screen within the Aventa fitting software (Figure 4). The numbers on the individual environmental sliders are in dB. Positive numbers increase overall gain in the specified acoustic environment, negative numbers conversely decrease the gain when the specific environment is encountered.

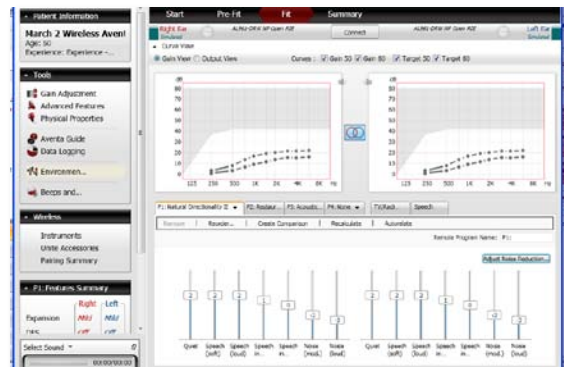


Figure 3. The Environmental Optimizer II screen is an easily accessible tool in the Aventa3 fitting software.

The “Adjust Noise Reduction per Environment” button located in the Environmental Optimizer II display will open the screen shown in Figure 5. Here the NoiseTracker II level can be set per environment. As shown in Table 1, the initial per environment settings are defaulted to provide the most aggressive noise reduction for noisier sound environments and the least noise reduction for quiet and speech only environments.

	Quiet	Speech (soft)	Speech (mod.)	Speech in noise (mod.)	Speech in noise (loud)	Noise (mod.)	Noise (loud)
NoiseTracker II level	Mild	Mild	Mild	Moderate	Moderate	Considerable	Strong
Max reduction (dB)	-4	-4	-3	-6	-6	-8	-9

Table 1. Default NoiseTracker II settings in the Environmental Optimizer II.

The noise reduction value depicted on the sliders is the amount that would be applied when the estimated SNR is 0 dB or worse. Five different noise reduction options ranging from none to strong noise reduction are available for seven of the most probable listening environments. Regardless of setting, Noise Tracker II will apply appropriate

noise reduction in situations when the input sound falls in between categories.

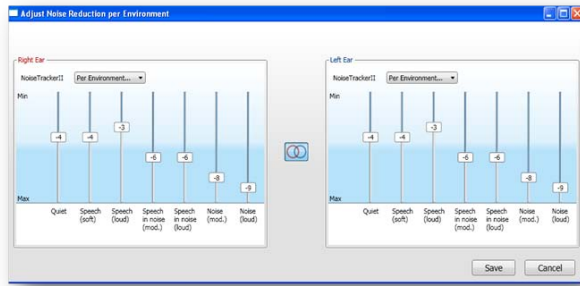


Figure 5. NoiseTrackerII levels can be set per environment in Environmental Optimizer II.

SUMMARY

The advantages of the Environmental Optimizer II are expansive; the environmentally classified gain and noise reduction settings can be distinctively set for each individual's unique needs and preferences. Fitters can now make gain and noise reduction changes based on listening environment complaints without having to universally impact gain in all situations. The precise classification system and accurate noise reduction strategy allows for a more pleasurable sound experience. With Environmental Optimizer II, the user is able to have the greatest opportunities for improved hearing in multiple environments and

optimum sound processing for comfort and hearing in noise.

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