

## ReSound Directional Options

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### Abstract

Hearing instruments with directional characteristics were developed to address the numerous, complex demands of everyday listening. An omnidirectional microphone response might be preferable in some listening situations, while a directional response might be desirable in others. Yet real-world listening environment demands and hearing aid user intentions rarely are satisfied with a single directional or omnidirectional choice. In many cases, improved speech understanding in noise, a directional benefit, is desired in conjunction with the omnidirectional benefits of environmental sound awareness and spatial perception. ReSound recognizes that there is no one ideal microphone response pattern for all individuals in every situation. For this reason, the surround sound by ReSound technology package offers five microphone response options to provide maximum flexibility when fitting patients. Included among these options is Natural Directionality™ II, which enables hearing aid users to enjoy the benefits of directional and omnidirectional signal processing simultaneously. In this article, benefits of and suggested uses for all of these directional options are discussed.

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Understanding speech in background noise is a primary problem for individuals with hearing losses. While hearing instruments can provide increased audibility, difficulties with background noise often persist. The best way to improve speech understanding in background noise is to increase the signal-to-noise ratio (SNR). An increased SNR can be achieved through the use of directional microphones. Commonly used directional microphone systems assume the desired signal is located in front of the listener, or in what is considered the “look direction.” Sounds originating from other directions are often considered noise, and the amplification for these signals is decreased.

Directional hearing aids, while beneficial in increasing the SNR, may introduce other problems. Many users experience diminished audibility for sounds of interest that do not arise from the front, or the “look direction.” As sounds from the sides and the rear are reduced in amplification, users may report a feeling analogous to tunnel vision. That is, they may have a sensation of being cut off from much of their surroundings, resulting in a skewed or surreal perception of the listening environment as a whole.

Other issues have been reported regarding practical use of directional hearing aids. While specific directional characteristics should be preferred in specific situations, research has shown that over 30% of individuals with manually switchable omnidirectional/directional hearing aids do not change between these modes (Cord et al., 2004). Reasons for this include the user not knowing when to switch, and/or not wanting to make these manual adjustments in their daily hearing aid use.

A solution to this problem is automatically-switching directionality, in which the hearing aid selects a directional or omnidirectional response

depending on an analysis of the acoustic environment through sound level and speech detection algorithms. Yet this solution is still not fail-safe, since automatically-switching algorithms do not always respond in the way the listener would like. Occasionally, the hearing aid selects the wrong microphone response, either through incorrect analysis of the acoustic environment or assumptions based solely on the environment and not on the user’s intent. For example, listeners may prefer omnidirectional processing in some noisy environments (Walden et al., 2004). Automatically-switching algorithms are limited solely to acoustic environment analysis, and have no ability to determine the hearing aid user’s intent in some complex listening situations.

Asymmetric directional processing, in which one ear receives a directional response while the other receives an omnidirectional response, was developed to address the concerns with automatically-switching algorithms. This option provides improved SNR benefits for sounds arising from the front, while maintaining maximum auditory awareness for sounds arising from any direction. The hearing aid user benefits from both types of processing at the same time, and avoids errors that can occur with automatically-switching directionality.

Natural Directionality™ II is an advanced asymmetric directional fitting algorithm which considers the listener’s perception of the acoustic environment and overall sound quality through the ReSound surround sound processor. The end result is amplification with a more natural sound quality, improved speech understanding in noise, and better localization cues.

To promote greater fitting flexibility, ReSound features five distinct microphone response options:

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## ReSound Directional Options

Omnidirectional, Fixed Directionality, MultiScope Adaptive Directionality™ with AutoScope, SoftSwitching™ and Natural Directionality™ II. This menu of options allows for highly personalized, state-of-the-art hearing aid fittings. In particular, Natural Directionality II provides a more realistic, holistic listening experience.

### ReSound surround sound processor

A surround sound listening experience is one in which the listener is immersed in three-dimensional sound. This is how normal-hearing listeners typically experience the acoustic environments around them. However, users of directional hearing aids may not experience the real-world environment in this way due to reduced audibility for sounds not originating from the front. They may report that sound sources are difficult to localize and characterize as a result of this problem. The ReSound surround sound processor enables the hearing aid user to enjoy the benefits of directional processing while experiencing the actual listening environment in a more natural, less surreal way. This is achieved by processing the incoming signal based on its frequency content (Figure 1). High frequencies are processed as a directional response, while low frequencies are processed as an omnidirectional response. This spectral preservation of low-frequency sounds allows the user to take advantage of natural between-ear phase differences, which aid in sound localization and promote better sound quality.

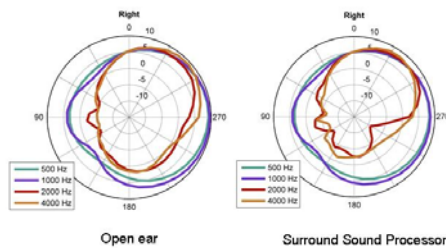


Figure 1. Open ear response compared to the surround sound processor for low and high frequencies.

By applying an omnidirectional response to low-frequency sound inputs, the surround sound processor also alleviates other issues that traditionally have been inherent in directional hearing aid use. One of these issues is noise as a result of the equalization, or “bass boost,” of the low-frequency roll-off of directional amplification. This roll-off occurs because low-frequency sounds have similar phase relationships between the front and rear microphones. To accommodate for this decrease in audibility while in the directional mode, a boost in low-frequency amplification is typically applied. However, this may result in an audible noise floor which may detract from the

overall hearing benefit (Ricketts and Henry, 2002). By using omnidirectional processing in the low frequencies, this problem is avoided. In addition, the directional problem of overamplification of near-field signal distortions such as wind noise is reduced.

The Directional Mix pull-down menu in the Aventa 2.9 software allows for adjusting of the amount of high-frequency directional signal applied. It is applied to all directional modes, and can be set for each individual program based on the user’s listening needs. Directional Mix settings are Very Low, Low, Medium, and High, with a higher setting indicating more directional signal processing is provided. In the figure that follows, a higher Directional Mix setting would have a greater proportion of directionality than a lower setting. Figure 2 shows the smooth transition between the omnidirectional and directional signals resulting in noise-free natural-ear directionality.

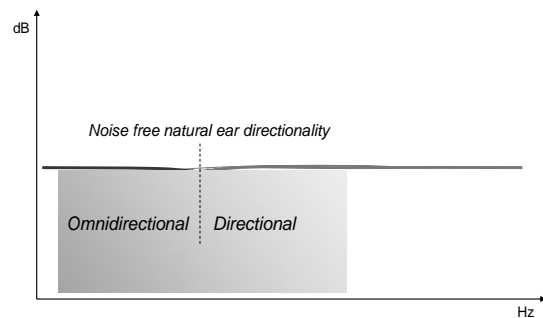


Figure 2. Natural ear directionality with a smooth transition between omnidirectional and directional responses.

The frequency at which the processing of the input signal changes between omnidirectional and directional is called the “blending point.” The blending point is automatically calculated by the Aventa fitting software by averaging the hearing loss thresholds for 250 and 500 Hz bilaterally, and is also dependent on the hearing aid model chosen. In general, if the average of a hearing aid user’s right and left thresholds at these frequencies is less than 40dB, the Directional Mix is set to a lower level (a higher blending point). This setting reduces the bass boost-induced low-frequency noise the user may have experienced with traditional directional processing. Conversely, if the average is greater than 40dB, the Directional Mix is set to a higher level (a lower blending point), as low frequency noise would be less audible to this user. The Directional Mix is automatically set to the same level for each program, but may be changed in an individual program through the Directional Mix pull-down menu.

## ReSound Directional Options

The five directional options offered with the ReSound surround sound processor are designed to be fitted according to the hearing aid user's needs. A description of these options with examples of when they optimally would be used follows.

### Option 1: Omnidirectional

In an omnidirectional mode, the hearing aid amplifies sounds arising from all directions. As only omnidirectional processing is applied, there is no Directional Mix. This mode may be preferable when the user is in a quiet environment. An omnidirectional response is also the default setting for the "Music" program, since the incoming signal is not altered or skewed to improve audibility in any direction. In addition, the omnidirectional mode offers the listener natural spatial perception cues, which are beneficial if a "Traffic" program is desired.

### Option 2: Fixed Directionality

The fixed directional mode has a static, unchanging hypercardioid directional response pattern. In this mode, the environmental input is amplified more for sounds from the front than for sounds from the sides and rear. It may be applied in "Restaurant," "Party" or other programs designed for noisy environments. Individuals who prefer more traditional directional processing patterns, such as in their previous hearing aids, may benefit from this setting.

### Option 3: MultiScope Adaptive Directionality™ with AutoScope Adaptive Directionality™

ReSound's MultiScope Adaptive Directionality provides various directional characteristics that adapt based on the intensity and direction of the noise. Sound level and speech detection algorithms determine whether omnidirectional or directional processing is advantageous, based on the sound inputs received at the microphones. If the SNR is high (8dB or greater), as in a quiet environment, the omnidirectional response is automatically selected. If the SNR is lower than 8 dB, as is typical in noisy environments, a directional response is utilized. The directional response cancels the strongest noise source behind the user, and can also cancel multiple noise sources in different spatial locations simultaneously when the frequency contents of the noise sources differ. For this reason, MultiScope Adaptive Directionality is the default directional setting for the "Restaurant" and "Party" hearing aid programs.

The Adaptive Directionality will also steer the directional beam toward the front instead of being skewed to the ear wearing the hearing instrument. Three MultiScope settings of Narrow, Medium and

Wide correspond to listening scopes of +/- 50, 70, and 90 degrees, respectively.

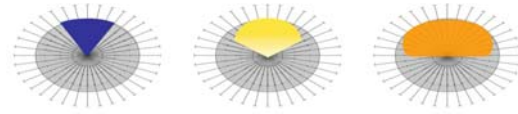


Figure 3. MultiScope Adaptive Directionality settings.

ReSound introduces the option of AutoScope, which automatically adjusts the directional beamwidth based on the relative levels of inputs to the front and rear microphones. As the signal to the front microphone becomes more intense, the scope narrows. Alternately, as the signal to the front microphone becomes less intense, the scope widens, allowing more audibility for surrounding sounds. This creates an effect of zooming in on the speakers if they are directly in front of the listener, and zooming out when the listener is surrounded by many speakers. The AutoScope setting is the default beamwidth for MultiScope Adaptive Directionality.

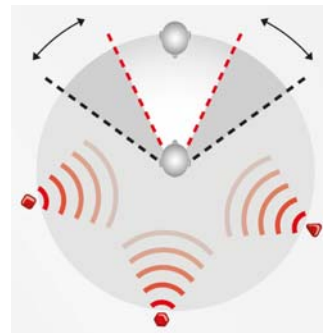


Figure 4. ReSound AutoScope Adaptive Directionality.

### Option 4: SoftSwitching™ Adaptive Directionality

SoftSwitching also uses knowledge about directional preferences along with acoustic analysis of the listening environment to control whether the hearing aid processes in an omnidirectional or directional mode. Like MultiScope Adaptive Directionality, SoftSwitching uses sound level and speech detection algorithms to decide when directionality is likely to be advantageous in a certain listening environment. It also offers the same four selections of MultiScope beamwidth settings: the default AutoScope, Narrow, Medium and Wide. The SoftSwitching mode differs from MultiScope Adaptive Directionality in that it uses slower transitions between directional settings and the omnidirectional setting, which is sometimes more comfortable and preferable among certain hearing aid users.

### Option 5: Natural Directionality™ II

Natural Directionality II provides the listener with the benefits of both omnidirectional and directional modes simultaneously. This option eliminates the need for manual or automatic switching between omnidirectional and directional modes, as both modes are always available to the listener. The omnidirectional pattern is applied to one ear, termed the “monitor” ear, and the fixed hypercardioid directional pattern is selected for the other ear, termed the “focus” ear. The focus and monitor ears are designated through the Focus Ear Calculator in Aventa. The benefits of Natural Directionality II are environmental sound awareness (an omnidirectional benefit) with improved speech understanding to the front (a directional benefit). Lab studies have shown no significant difference in directional benefit between asymmetric directionality fittings and bilateral directional fittings (Bentler et al., 2004, Cord et al., 2007 and Mackenzie and Lutman, 2005). In addition, improved ease of listening for asymmetric directional fittings as compared to bilateral directional fittings has also been noted (Cord et al., 2007). This improved ease of listening occurs due to the availability of environmental sound inputs from the monitor ear, which does not occur in bilateral directional fittings. Users do not feel as isolated from sounds originating from the sides and rear due to the environmental sound cues from the omnidirectional processing that is always available to them in this mode.

ReSound’s Natural Directionality II incorporates the surround sound processor and its Directional Mix to further improve upon asymmetric directional processing. The frequency responses for both ears are synchronized in Natural Directionality II to maintain interaural time differences (ITDs) between the ears. This important development minimizes phase and processing differences between the focus and monitor ears. The low-frequency omnidirectional responses also help to equalize loudness perception of sound sources in the environment. The cumulative result of these improvements is maximized spatial hearing ability and more natural sound quality.

In Natural Directionality II, the improved Focus Ear Calculator introduces the use of speech-importance weighting for audiometric thresholds in addition to any available speech testing results to determine the optimal focus ear designation. However, the Aventa fitting software still allows for the focus and monitor ears to be set manually. This flexibility allows for further personalization of the Natural Directionality II program fitting. Due to its end-user advantages, Natural Directionality II is

the default setting for the first program in binaural fittings with directional microphones.

### Discussion

ReSound provides an assortment of directionality options to meet the individual needs of the listener. This degree of flexibility allows for a personalized fitting to a wide variety of listening situations. In particular, Natural Directionality™ II in conjunction with the advantages of the surround sound processor provide the user with the most natural listening experience through both directional and omnidirectional signal processing.

### References

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