ReSound's Directional Philosophy

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Financial disclosure

- John A. Nelson is employed as the Vice President of Global Audiology Relations at GN ReSound and has financial relationships in the products and services communicated, compared and evaluated in this presentation.

Learner Objectives

- Describe basic directionality techniques including improving sound quality and automatic switching.
- Describe the benefits of ReSound's Natural Directionality II (asymmetric directional) in terms of directional benefit and environmental awareness
- Describe the benefits of ReSound's Binaural Directionality II with Spatial Sense and the listening environments where they are beneficial.

Directional Foundations

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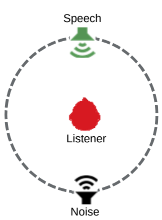
Directional benefit in laboratory settings

- Extensive research on directional benefit
- Most evaluation in controlled laboratory environment
- Spatially separated: Speech from the front and noise from behind
- Directional microphones can provide a large benefit in these controlled situations



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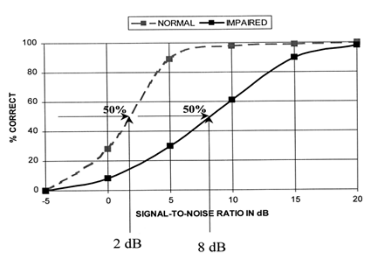
Benefits of directional microphones



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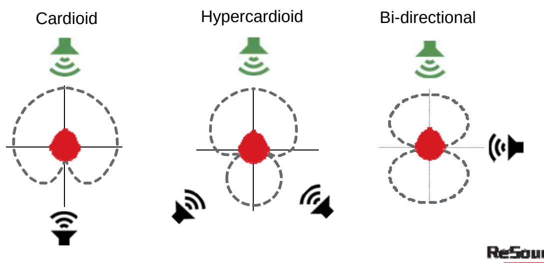
Examples of polar characteristics



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Sound Quality and Directionality

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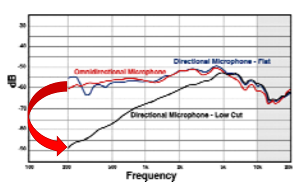
Directional mode low-frequency roll off

- Low-frequency wavelength exceeds the distance between the microphones
- Results in reduced low-frequency hearing aid output and reduced audibility of low-frequency sounds
- Cutoff frequency dependent on microphone spacing



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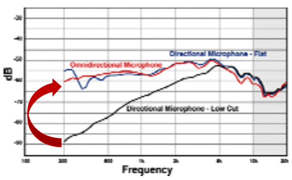
Directionality: Low-frequency equalization

- Increased low-frequency gain equalizes roll off and provides improved audibility
- Results in increased occlusion, noise, & wind noise



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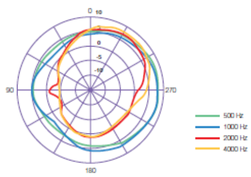
Head-related directional characteristics

- Low frequencies travel around the head with limited intensity changes, omni-directional pattern
- High frequencies are affected by head shadow an are more like a directional response



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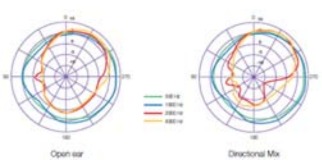
Directional Mix Processing

- Low frequencies are omni-directional – like the natural open ear
- High frequencies are directional – increased speech understanding
- Provides rich sound quality, enhanced speech understanding, and low-frequency localization cues



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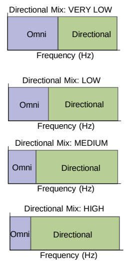
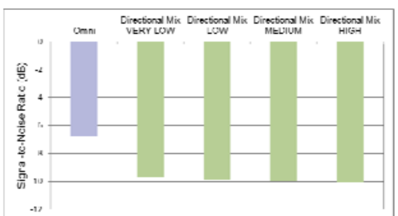
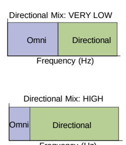
Directional Mix Processing: What is the Directional Mix?

- Directional Mix is the crossover frequency between omnidirectional and directional processing
- Aventa provides a unique prescription based on the individual's
  - Audiogram
  - Hearing aid selected



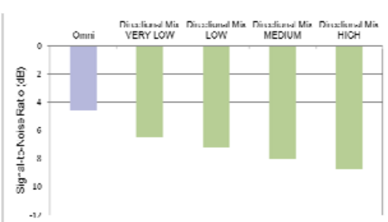
Directional Mix Processing: Benefit for open fittings

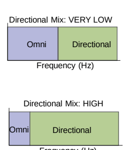




(Moeller & Jespersen, 2012)

Directional Mix Processing: Benefits for traditional venting

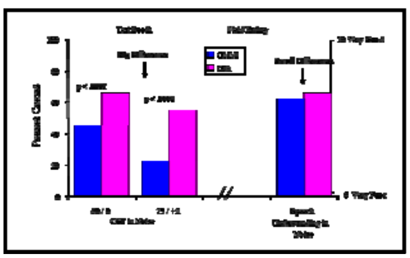




(Moeller & Jespersen, 2012)

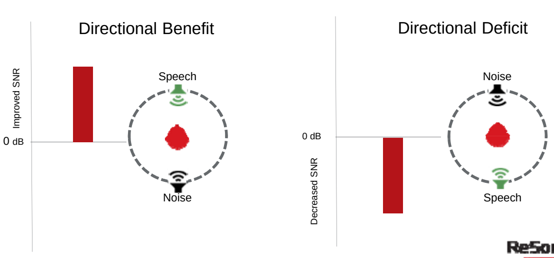
Automatic Directional Switching

Directional benefit: Real world?



Source: Efficacy Studies at Walter Reed Army Medical Center, Walden, Surr, & Cord, 2003

Directional: Benefit or Deficit?



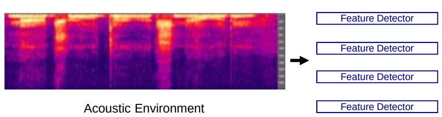
Note: Binaural omni-directional compared to binaural directional

Basic directional philosophies

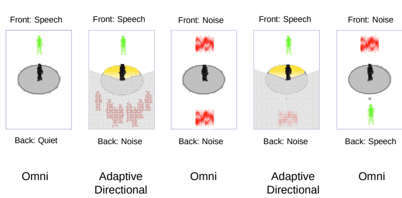
- Focus on improving SNR – typically front-to-back listening improvement
- Focus on automatic functionality
- Assumption that listener intent can be predicted based on acoustic analysis (acoustics in the environment instead of the listener's interest)
- Automatic directional philosophies are not ideal and in many situations are detrimental

Compensation for directional deficit

- Some automatic directional microphone algorithms will analyze the acoustic environment and focus on the 'loudest speech signal' instead of the front signal
- Assumes that the listener is interested in the 'loudest speech' signal which is not always the case



ReSound SoftSwitching

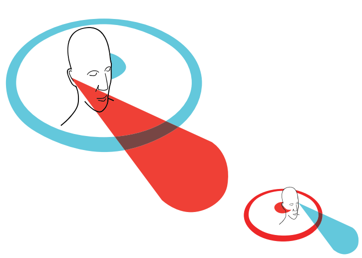


ReSound Natural Directionality II

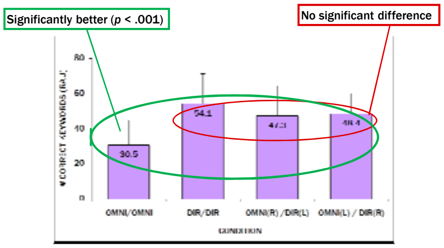
ReSound's directional philosophy

- Focus on providing natural perception
- Recognize that hearing instrument intelligence cannot replace auditory processing
- Apply technology to take advantage of brain's ability to integrate and segregate sound sources for a natural listening experience

ReSound Natural Directionality II



Asymmetric directionality: Laboratory results



Cord, Walden, Surr & Dittberner (2007). Field evaluation of an asymmetrical directional microphone fitting. JAAA

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ReSound Binaural Directionality

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Real world listening situations

- Real world listening situations are not controlled environments
- Bilateral omnidirectional is often preferred, especially in quiet and single speaker situations
- Bilateral directional is usually preferred if the speaker is in front of and near to the listener and noise is to the sides and the back
- Bilateral directional is not correct choice if speaker is not in front of the listener
- Thus, it is difficult to make automatic switching decisions on the acoustic environment

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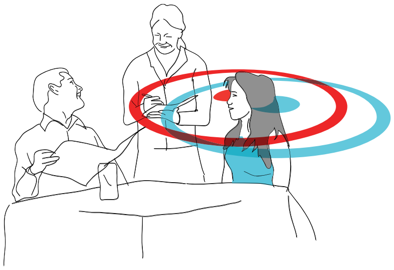
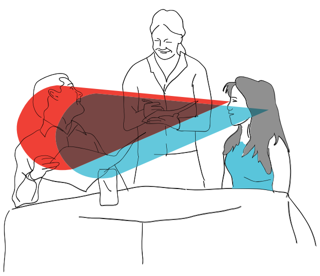
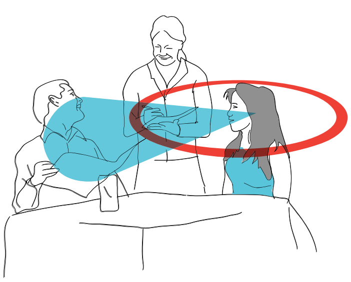
Omni/Omni mode



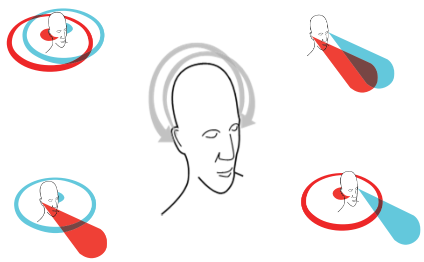
Directional/Directional mode



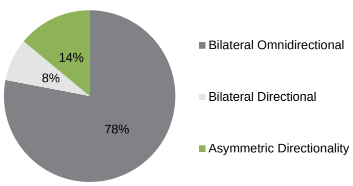
Asymmetric Directional mode

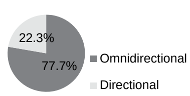


ReSound Binaural Directionality



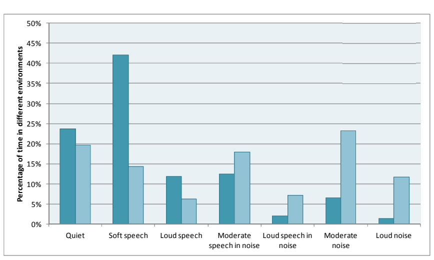
Binaural Directionality: Switching





Cord et al, 2002

Cases: Mr. Dark Blue & Mr. Light Blue



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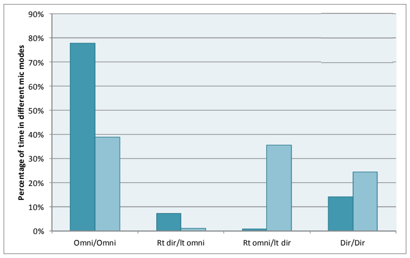
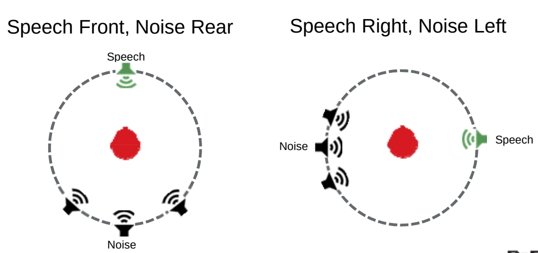


ReSound Binaural Directionality

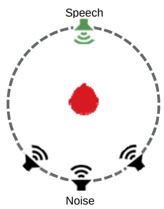
- Provides improved signal-to-noise ratio (front-to-back) as long as the signal of interest is in front of the listener and the competing signal is to the sides or the back.
- Provides awareness and audibility to sounds that are not in front of the listener when in an asymmetric directionality mode

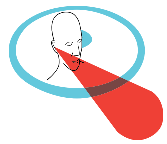
Challenging Acoustic Conditions



Natural Directionality II

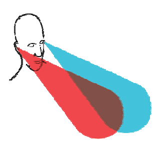
Speech Front, Noise Rear



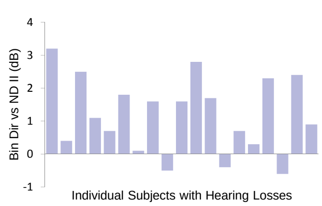


Binaural Directionality

Speech Front, Noise Rear

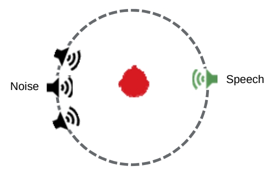


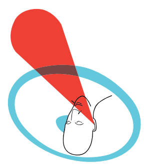
Results: Speech Front, Noise Back



Natural Directionality II

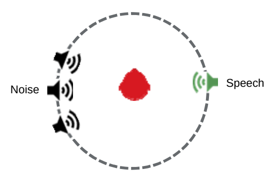
Speech Right, Noise Left



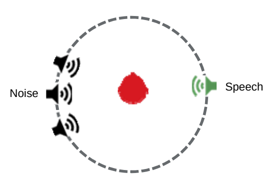


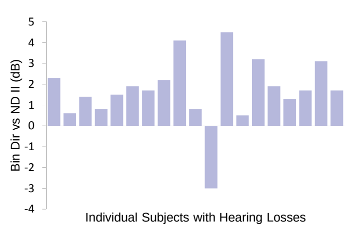
Binaural Directionality

Speech Right, Noise Left



Results: Speech Right, Noise Left





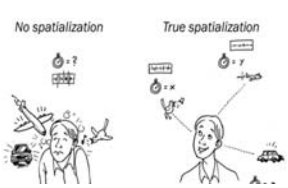
ReSound Binaural Directionality

- Provides improved signal-to-noise ratio (front-to-back) as long as the signal of interest is in front of the listener and the competing signal is to the sides or the back.
- Provides awareness and audibility to sounds that are not in front of the listener when in an asymmetric directionality mode

ReSound Binaural Directionality II with Spatial Sense

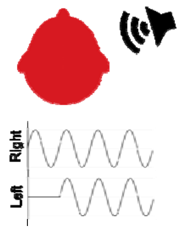
Spatial hearing: Why is it important?

- Allows an auditory image of the environment to be formed
- Spatial hearing also creates a sense of natural sound quality



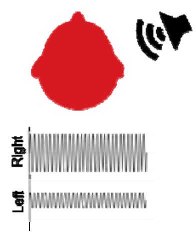
Interaural time difference

- When sound does not come from directly in front or behind, an interaural time difference occurs
- Time of arrival and phase differences of the sound between two ears are used by the brain
- Cues are detectable for low-frequency sounds and for the speech envelope, ITD is the dominate cue
- Dominant localization cue



Interaural loudness differences

- Sound diffracts off the surface of the head, creating a “shadow” on the side away from the source
- Sounds at the far ear will be lower in intensity
- Cues are detectible for high-frequency sounds

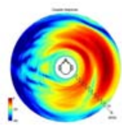


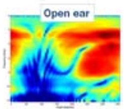
Preserving spectral cues

- BTE and RIE models have microphones placed above the pinnae
- Distortions to the spatial sound image as pinnae spectral cues are reduced compared to open ear
- Need to compensate for the artificial microphone position
- Dual microphone processing is applied to mimic an open-ear response

Spectral characteristics: Natural ear

- Head-related spectral cues are plotted by frequency, amplitude and azimuth (angle)
- Left graph: Low frequencies are closer to the center and higher frequencies are to the outer of the circle. Azimuth is the angle around the head in counter-clockwise rotation. Amplitude is by color.
- Right graph: Vertical axis is frequency (low-frequencies at the top). Horizontal axis is the azimuth or angle (counter-clockwise rotation).





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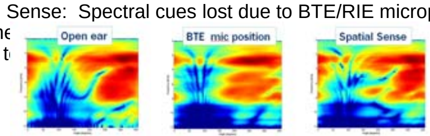
Spectral characteristics: BTE and RIE

- BTE microphone position: Spectral cues are distorted as signal travels to the top of the pinna to BTE microphone location and pinna, concha, and ear canal resonances and shadows are eliminated
- Spatial Sense: Spectral cues lost due to BTE/RIE microphone placeme
similar t



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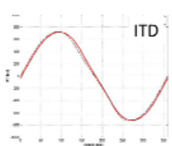
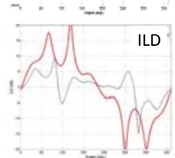
ITD preserved: Directional Mix Processing

- Desired open-ear response is red line
- ReSound e2e is the black line
- ITD preserved
- ILD errors can reduce sound quality as it will sound less natural if spatial cues not maintained





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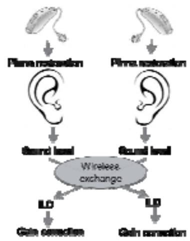
Spatial cue processing

- Pinna restoration applied (BTE & RIE) to accommodate for lost spectral characteristics due to microphone placement
- Sound level at the hearing instrument microphone is recorded to determine the interaural level difference (ILD)
- Data wirelessly exchanged between devices for compression compensation preserving the ILD



Non-Linear Amplification and ILD

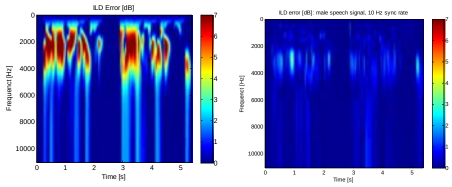
60dB SPL	Unamplified ILD = 10dB	70dB SPL
10dB	Non-Linear Gain	5dB
70dB SPL	Non-Linear ILD = 5dB	75dB SPL

Non-Linear Amplified ILD error = 5dB

Spatial Sense: Mimics inhibitory function

60dB SPL	Unamplified ILD = 10dB	70dB SPL
10dB	Non-Linear Gain	5dB
-5dB	Spatial Sense Correction	0dB
65dB SPL	Spatial Sense ILD = 10dB	75dB SPL

Spatial Sense processing: ILD correction



Compression introduces ILD errors
Indicated by the more red color

Spatial Sense removes ILD errors
Indicated by the more blue color

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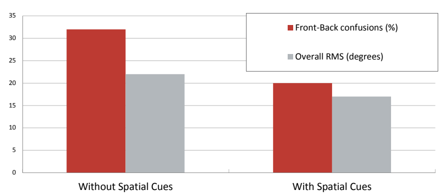
Benefits: Spatial cues



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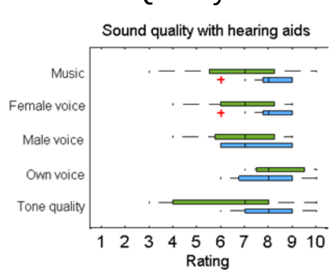
Benefits: Sound Quality



Green: e2e directionality without spatial cues
Blue: e2e directionality with spatial cues

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ReSound directional focus

- Provide improved audibility of desired signal
- Provide audibility for important signals
- Do not remove listener from acoustic environment
- Provide high sound quality