Hearing aid features that make a difference to your patients

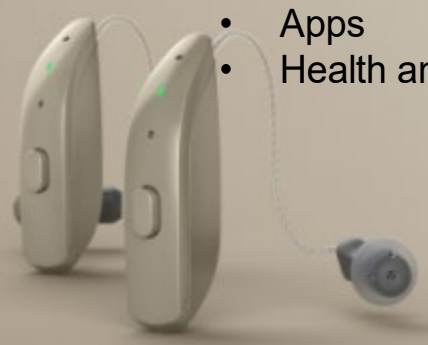
Jennifer Groth, MA

What are hearing aid features?

Sound processing features
- Amplification
- Directionality
- Noise reduction
- Feedback canceller

Functional features
- Rechargeability
- Connectivity
- Remote care
- Apps
- Health and fitness

Hardware features
- 2 mics
- Pushbutton
- Color
- LED
- Tcoil



Features that control other features
- Automatic program
- Environmentally dependent
- “Black box”

Feature versus technology:

- Digital processing capabilities
- Ear-to-ear communication/streaming
- Sensors
- AI

HA owner awareness of features

Table 3 Percent of Hearing Aid (HA) Owners who Report Having Each of the Listed Features in Each Fitting Channel

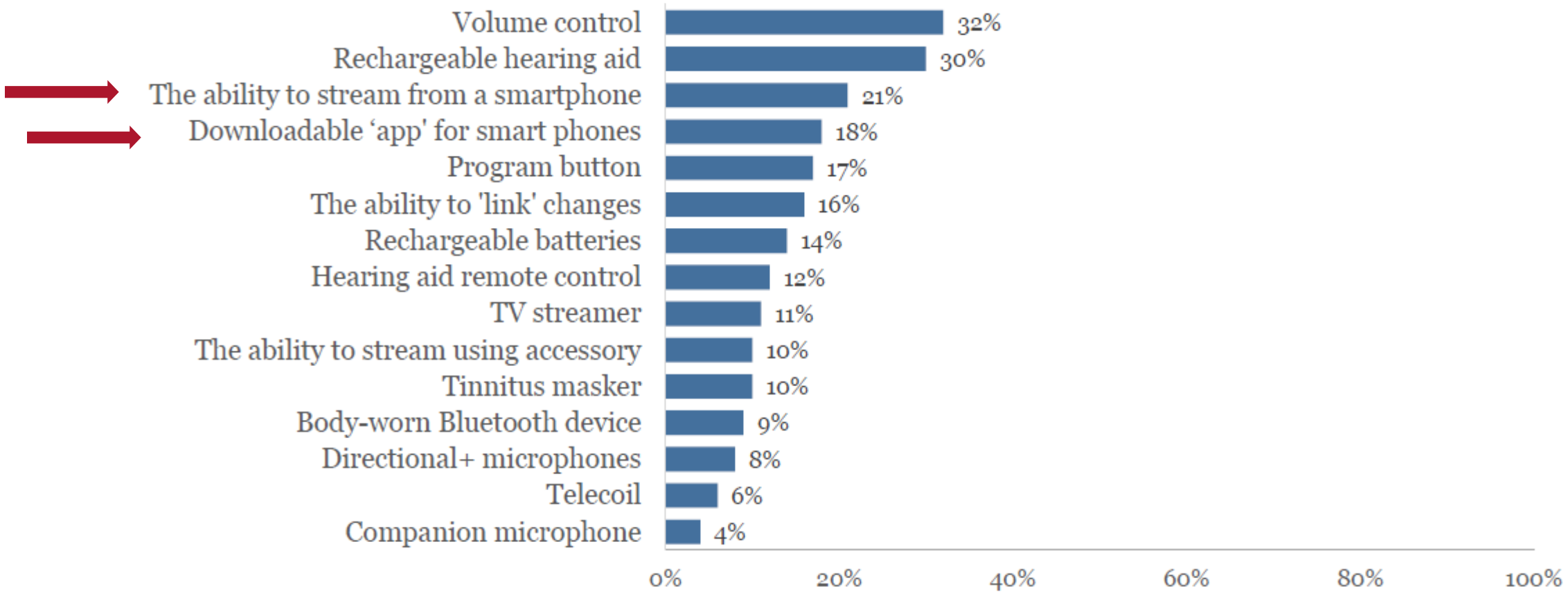
HA features Question: Below are some different HA features. Please indicate whether your current HA has each feature, as far as you know.	Got HA(s) *in past 5 y* by channel (% Yes)		
	In-person fitted ($n = 716$)	Remote fitted ($n = 51$)	Self-fitting ($n = 48$)
• **Volume control** on the HA itself	71%	73%	85%
• **Program button** or switch to change the HA response for different listening environments, like "Restaurant," "Outdoors," "Phone," etc.	50%	67%	62%
• **Rechargeable HA** which includes an integrated rechargeable battery that is never removed	50%	64%	63%
• **Directional, dual, twin, or multiple microphones** for enhanced hearing in noisy situations	36%	53%	47%
• **Rechargeable batteries** for hearing aids	31%	62%	47%
• **Telecoil** for use with the telephone or for listening in public places that have a special "hearing loop" sound system designed to communicate wirelessly with some hearing aids	29%	59%	43%
• **Tinnitus masker**, which masks or reduces the negative effects of tinnitus	26%	51%	35%

MarkeTrak 2022 (Picou 2023)

Most Impactful Feature, Capability or Accessory

(HA Owners with 4 or More of Items Below – Customized to Each Owner's Set
Owners who got HA in last 5 years (n=501))

- Could select up to 3-



MarkeTrak 2022

Impact of connected smartphone apps

Gomez et al, 2022 identified patient-reported barriers and facilitators to using smartphone connected hearing aids.

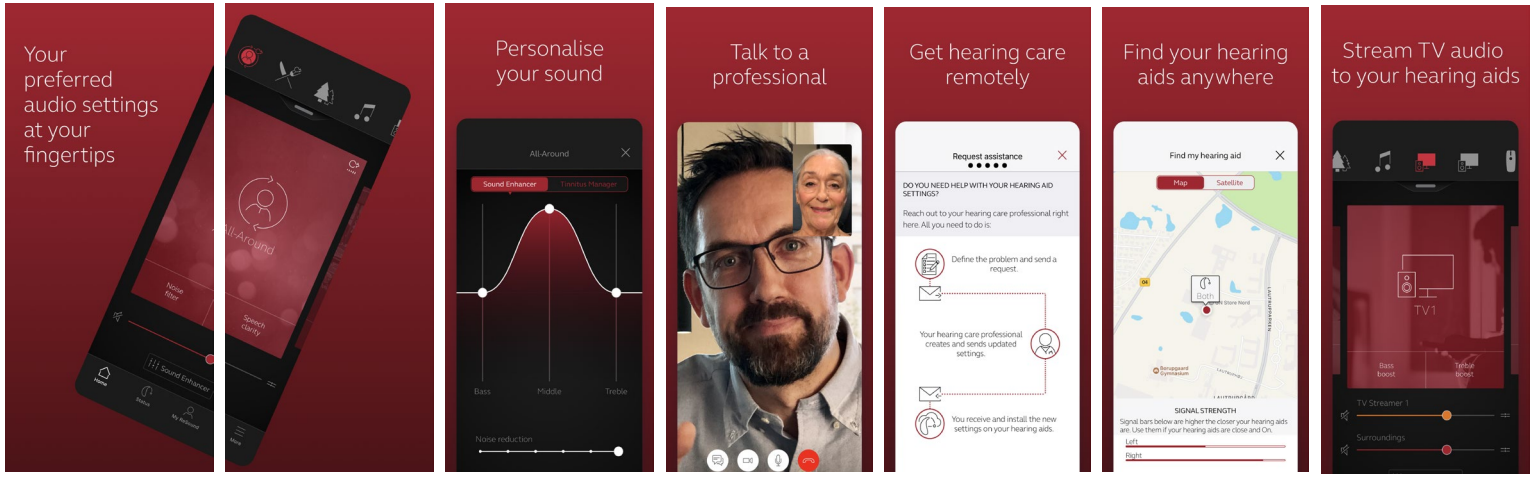
Empowerment

- Increased knowledge of hearing aid controls, encouraging app use for self-management

Reduction of hearing-aid related and self-stigma

- Others had positive perceptions of smartphone connected hearing aids
- Reduction in feelings of embarrassment and helps acceptance of using hearing aids

ReSound Smart 3D app



How do users use the app?

LAST 30 DAYS

AVG. Sessions per day

3.05

Change

74%

AVG Daily per user: 4.7

gram Selection

69%

AVG Daily per user: 3.9

LAST 30 DAYS

Quick Buttons

66%

AVG Daily per user: 3.0

LAST 30 DAYS

TSG

1%

LAST 30 DAYS

Find my Hearing Aids

20%

LAST 30 DAYS

Favorite Edited

8%

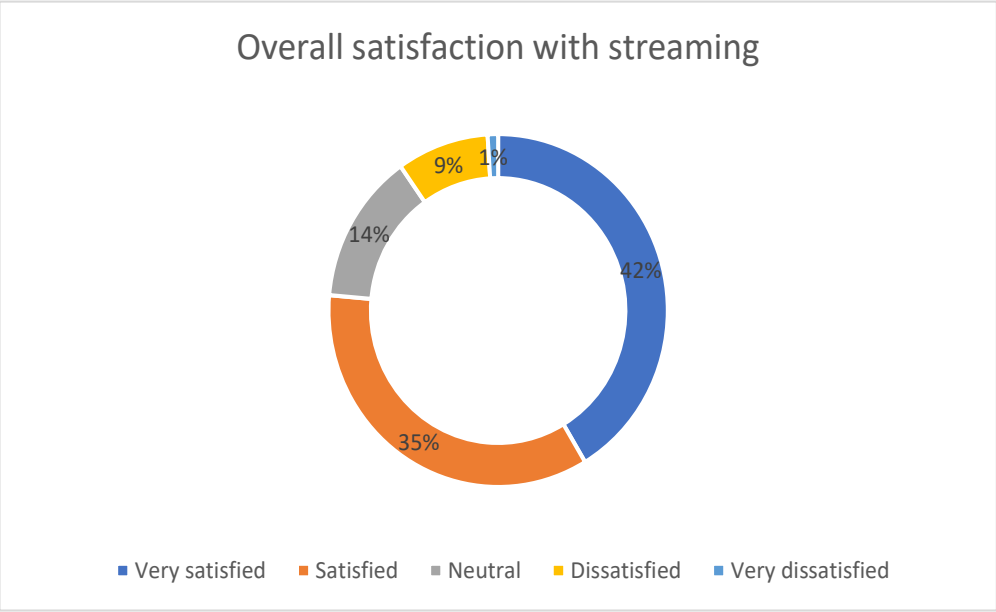
LAST 30 DAYS

Remote Service Request

2%

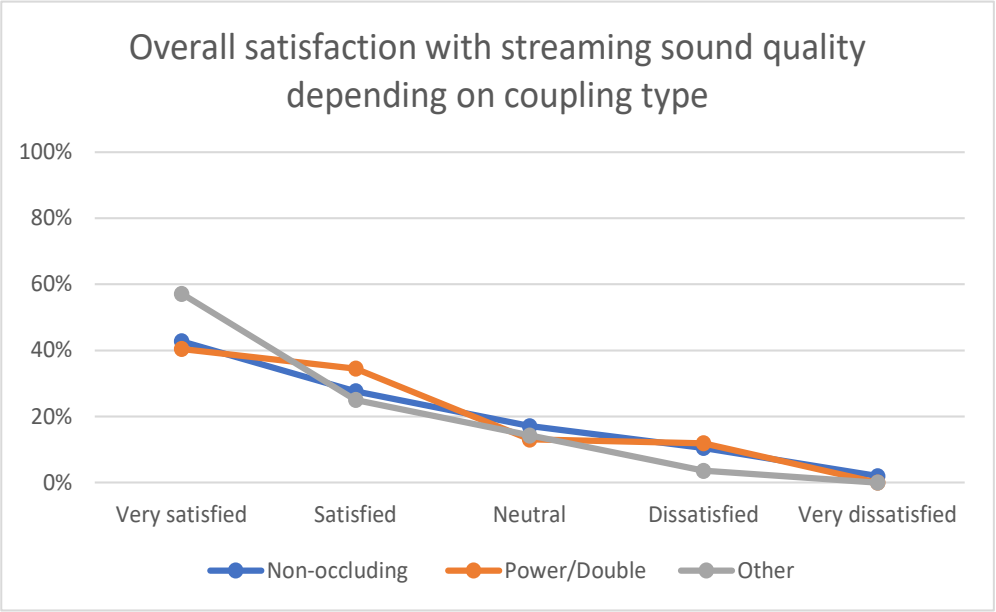
Impact of streaming

- 3rd most impactful feature in MarkeTrak 2022



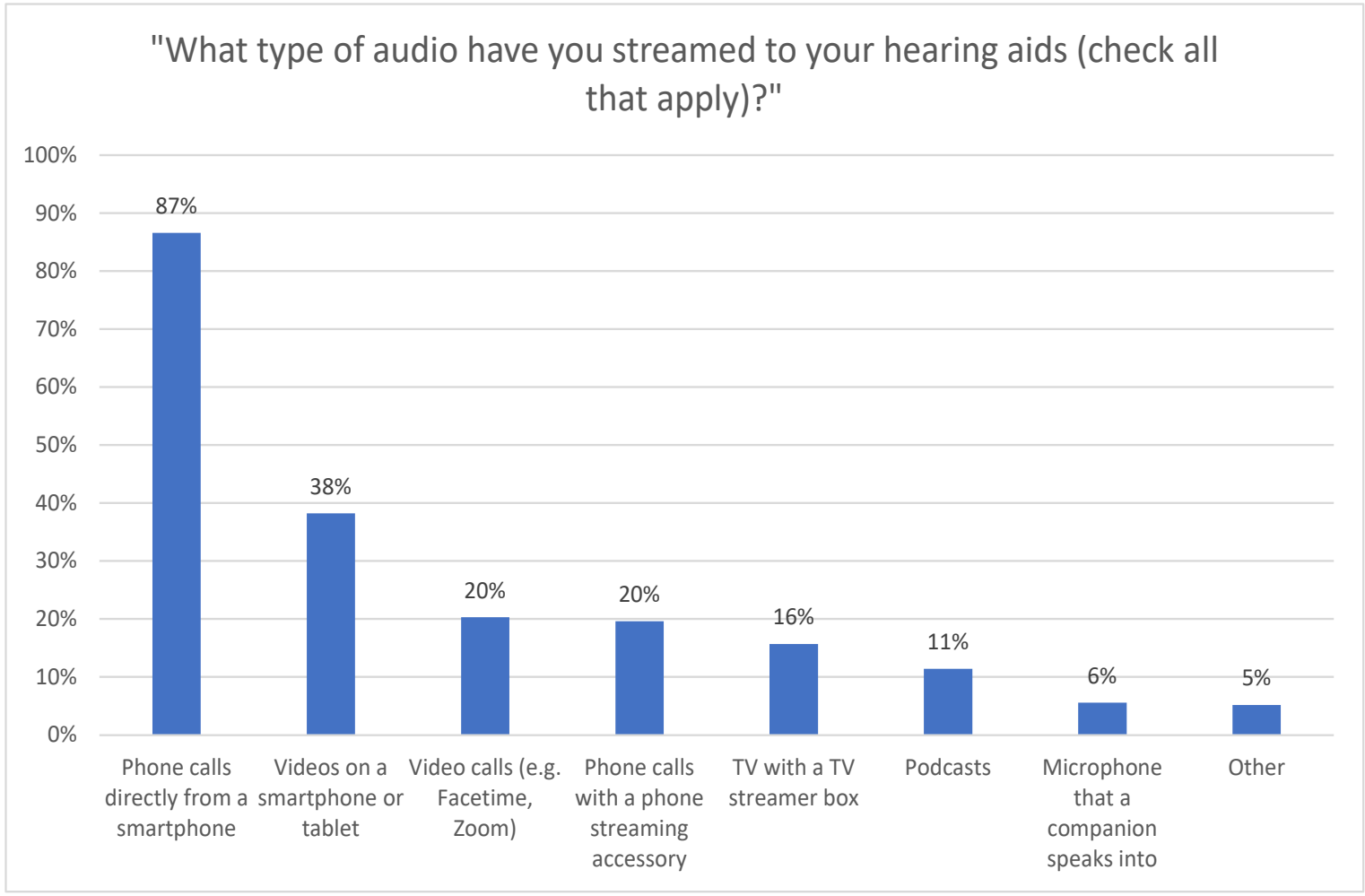
91% satisfaction with streaming capability

468 survey respondents (Groth & McCoy, 2023)

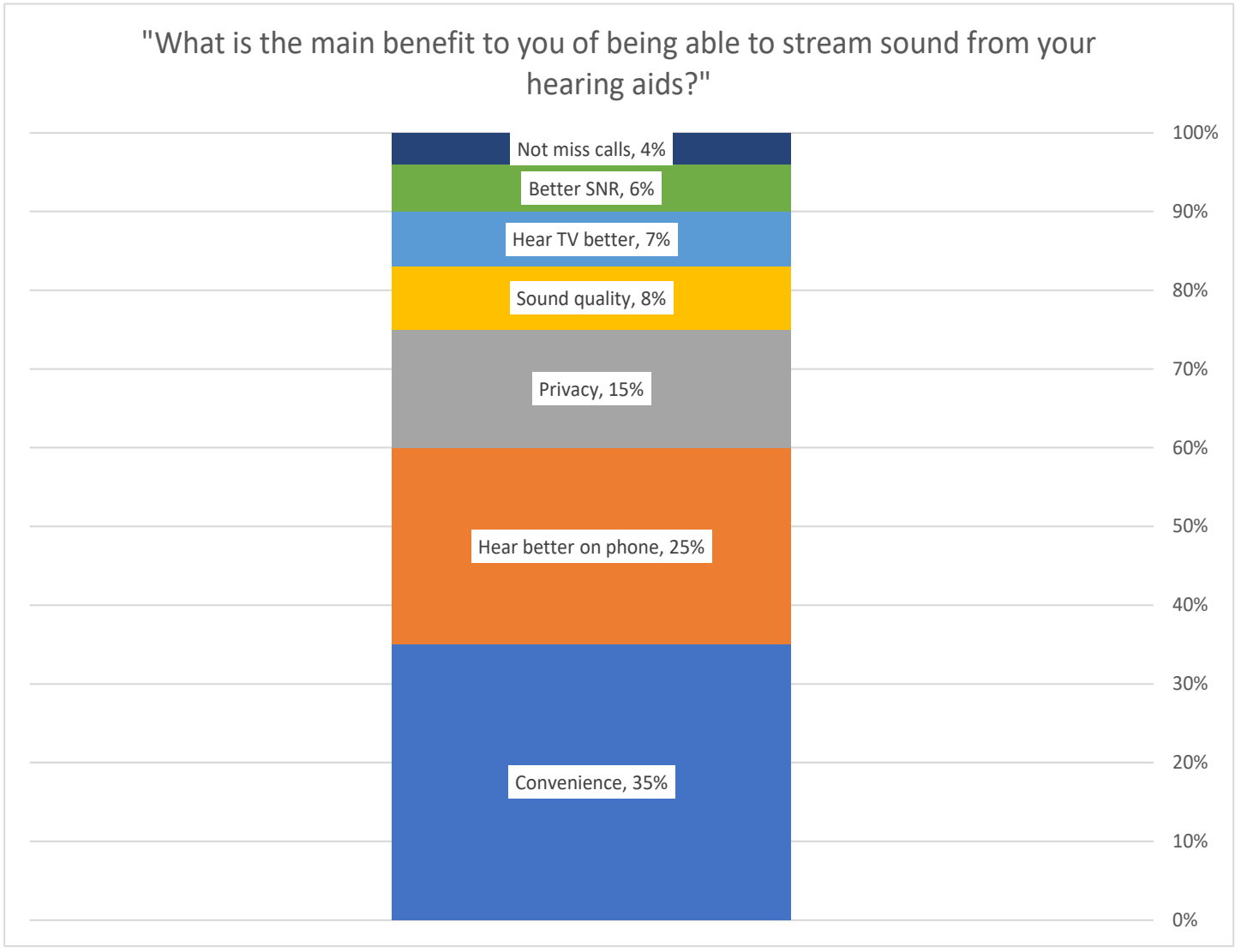


No significant dependence on coupling to ear

What are HA users streaming?



What benefits of streaming do HA users name?



The “feature” that always makes a difference

The hearing care professional

Across studies, the influence of the hearing care professional consistently affects patient outcomes with hearing aids.

Example 1:

The quality of service provided is related to overall success with hearing aids. Kochkin et al (2010)

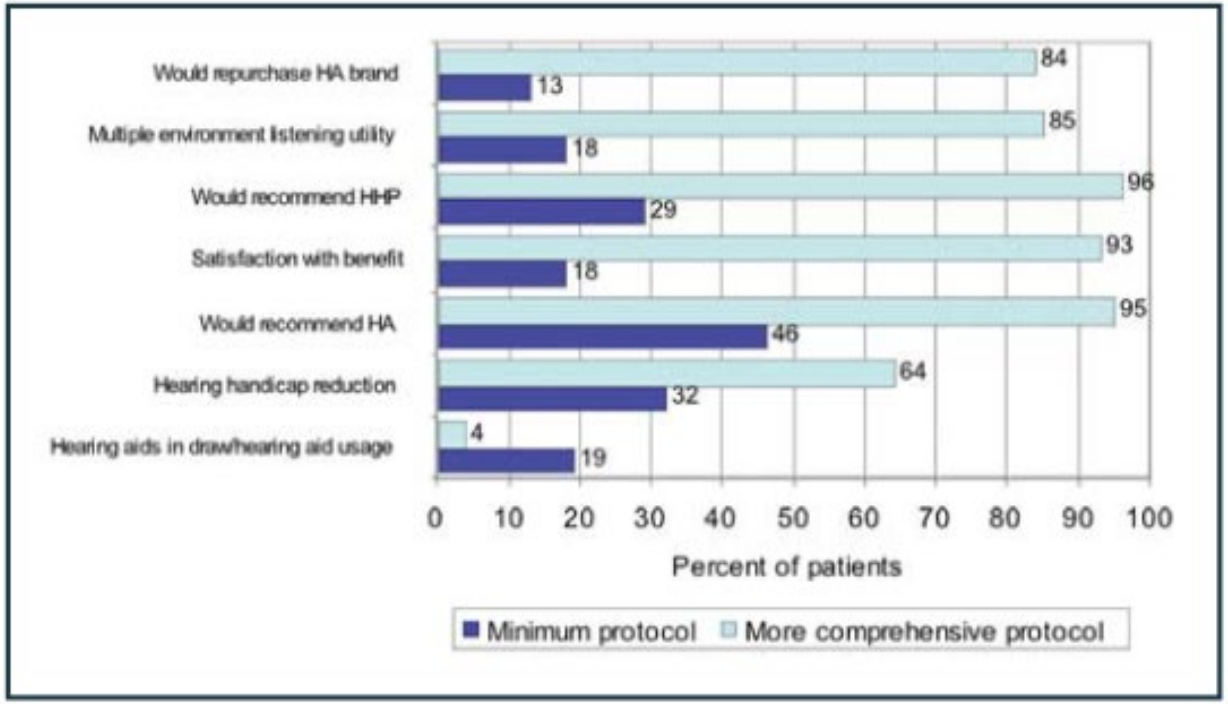


FIGURE 7B. Impact of a protocol on hearing aid success comparing a minimum protocol (0-2 items) to a more comprehensive protocol (10-12 items).

The hearing care professional

Across studies, the influence of the hearing care professional consistently affects patient outcomes with hearing aids.

Example 2:

What you say and how you say it affects patient experiences and outcomes.
Dawes et al (2013)

TABLE 2. Sound quality ratings for "new" and "conventional" hearing aids

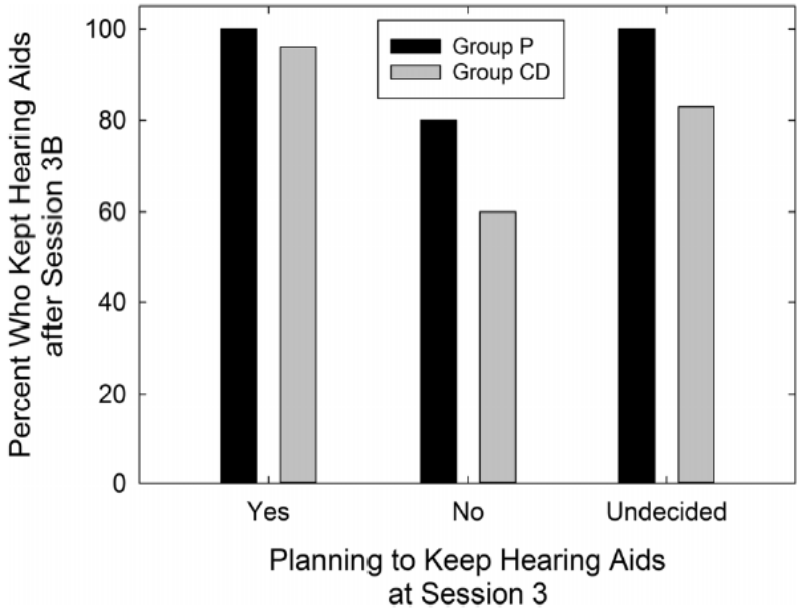
	Comfort	Clarity	Overall Impression	Overall Sound Quality Rating
Mean rating "new" (SD)	8.95 (1.12)	9.28 (1.15)	9.00 (1.11)	9.12 (1.02)
Mean rating "conventional" (SD)	8.40 (1.21)	8.61 (1.28)	8.1 (1.47)	8.35 (1.17)
*z**	−1.94	−2.77	−2.98	−2.88
p (two-tailed)	0.053	0.006	0.003	0.004
Effect size (*r*)	0.23	0.27	0.33	0.33

*Wilcoxon signed-rank test statistic.

The hearing care professional

Across studies, the influence of the hearing care professional consistently affects patient outcomes with hearing aids.

Example 3:



Best practices service and counseling increases purchase intent. Humes et al (2017)

Why do hearing aid manufacturers introduce new features?

A. Because patients benefit from the feature
B. Because they believe patients could benefit from the feature
C. They are fixing something in an existing feature
D. Because they can (the technology is available)
E. Because other brands have the feature
F. Because other brands do not have the feature
G. Because Hearing Care Professionals ask for/about the feature
H. Any combination of the above

Product/feature development philosophy

If the signal contains information the wearer wants to hear, it will be processed as ....., whereas if it contains unwanted or distracting sounds, it will be processed separately as .....

ReSound approach

Empower Human

Help from machine

A different approach

Empower Machine

Helps human

The ReSound Organic Hearing philosophy

The ReSound **Organic Hearing** philosophy enables people to connect to the world around them in the most intuitive and natural way. We achieve this by developing solutions that work with individual ear anatomy to more closely mimic how sounds in the environment are naturally collected and delivered to the brain.

This philosophy drives our history of innovations that deliver the whole sound picture so users can instinctively select the sounds they want to listen to - and tone down the ones they don’t.

Introducing a user

What do we know about our user?

His hearing problems are likely driven by hearing in noise

The biggest unmet need is hearing in background noise

Research shows that hearing aid performance, including hearing in noise, is the number one driver of hearing aid satisfaction

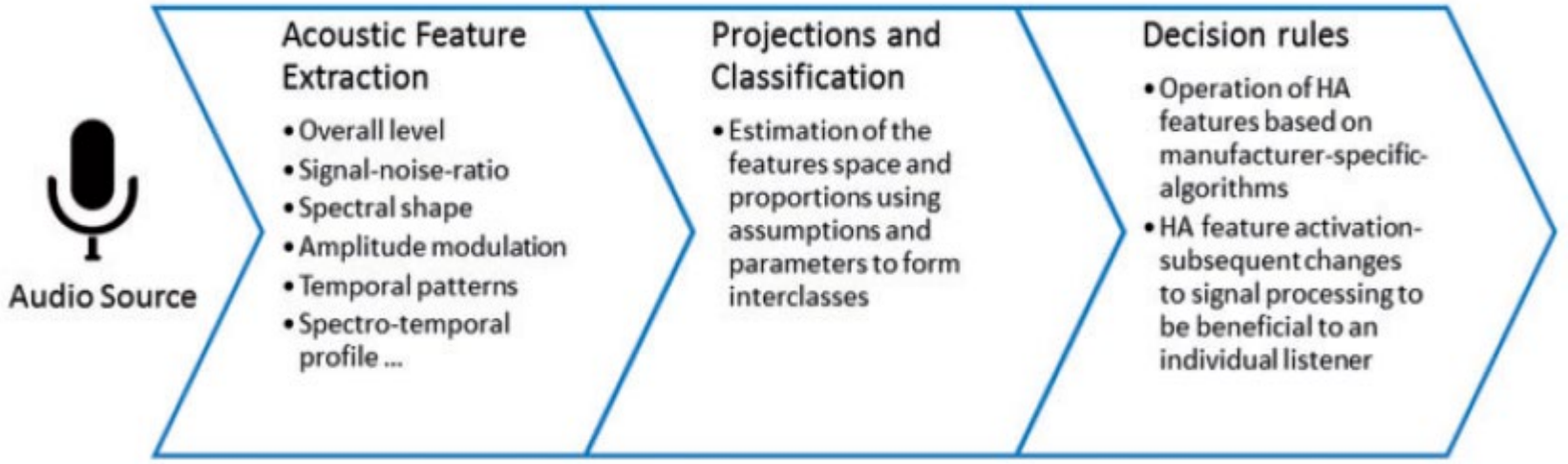
MarkeTrak 10, 2019
MarkeTrak 22, 2022
Picou, 2020

At ReSound, we focus on developing better technology for hearing in noise

Let’s start with the engine of the hearing aid

Environmental classification

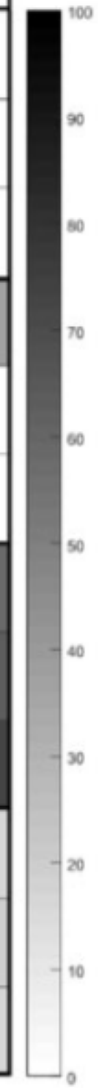
- Provides key input for decision-making on how and when to apply sound processing features
- “Comprehensive assessment of environmental classification is essential when considering the cost of signal processing errors, the potential impact for typical wearers, and the information available for use by clinicians. The magnitude of differences among devices is remarkable and to be noted.”



Yellamsetty et al, 2020

Humans

Ref.	Overall Level	Speech in Quiet						Speech in Noise						Noise						Music					
		S	A	B	C	D	E	S	A	B	C	D	E	S	A	B	C	D	E	S	A	B	C	D	E
2-person conversation	55	100	93	100	88	100	100	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0
	70	89	87	100	0	90	100	11	13	0	100	10	0	0	0	0	0	0	0	0	0	0	0	0	0
	85	89	94	100	6	25	100	6	6	0	82	75	0	6	0	0	12	0	0	0	0	0	0	0	0
Speech in noise at food court	55	22	10	1	0	3	1	77	64	99	100	93	63	1	26	0	0	4	0	0	0	0	0	0	36
	70	15	27	52	0	49	52	80	72	39	100	50	48	5	1	9	0	1	0	0	0	0	0	0	0
	85	17	38	23	0	5	62	73	61	77	100	94	38	6	0	0	0	1	0	6	0	0	0	0	0
Music, no noise	55	4	2	100	75	2	33	67	0	0	0	0	6	0	0	0	0	0	3	89	98	0	25	98	58
	70	0	1	11	0	1	5	0	0	26	0	1	24	0	0	0	0	0	7	100	98	63	100	98	64
	85	0	3	0	0	4	4	0	1	76	0	0	20	0	0	0	0	0	4	100	95	24	100	96	72
Music in card hall background	55	11	61	60	0	47	9	10	39	39	75	3	62	23	0	0	25	10	13	56	0	1	0	40	16
	70	0	1	0	0	2	1	44	2	100	0	98	69	13	97	0	100	0	11	43	0	0	0	0	19
	85	0	14	3	0	28	3	15	85	1	81	28	65	28	1	0	19	24	15	58	0	96	0	20	17



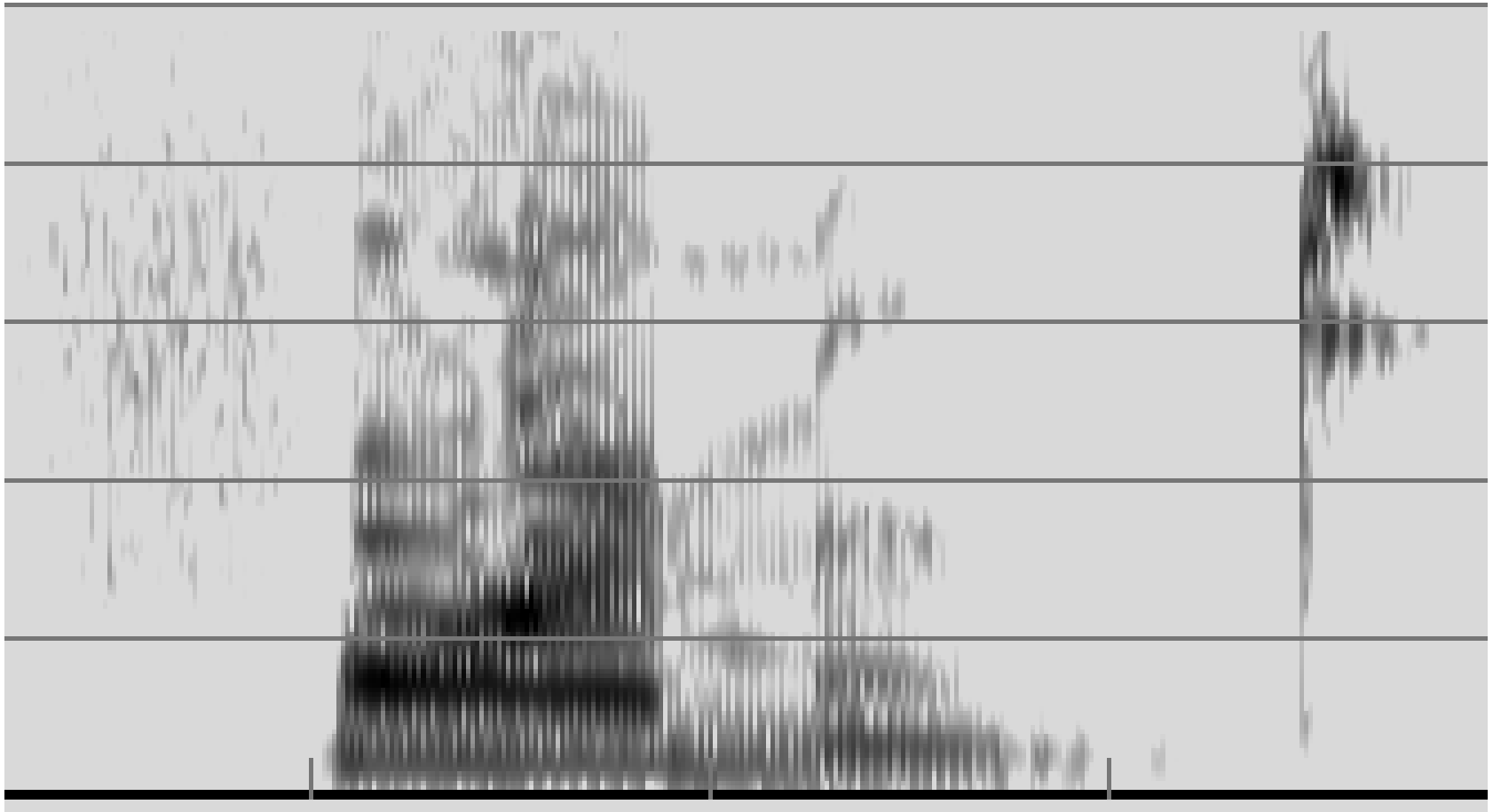
Yellamsetty et al. 2020

Environmental Classifier: 7 Environments

Sound inputs	Loudness	Environments
Quiet	Less than 54dB	**1. Quiet**
Speech	Less than 60dB	**2. Soft speech**
	More than 60dB	**3. Loud speech**
Speech in Noise	Less than 75dB	**4. Soft speech in noise**
	More than 75dB	**5. Loud speech in noise**
Noise	Less than 75dB	**6. Moderate noise**
	More than 75dB	**7. Loud noise**

Speech detector

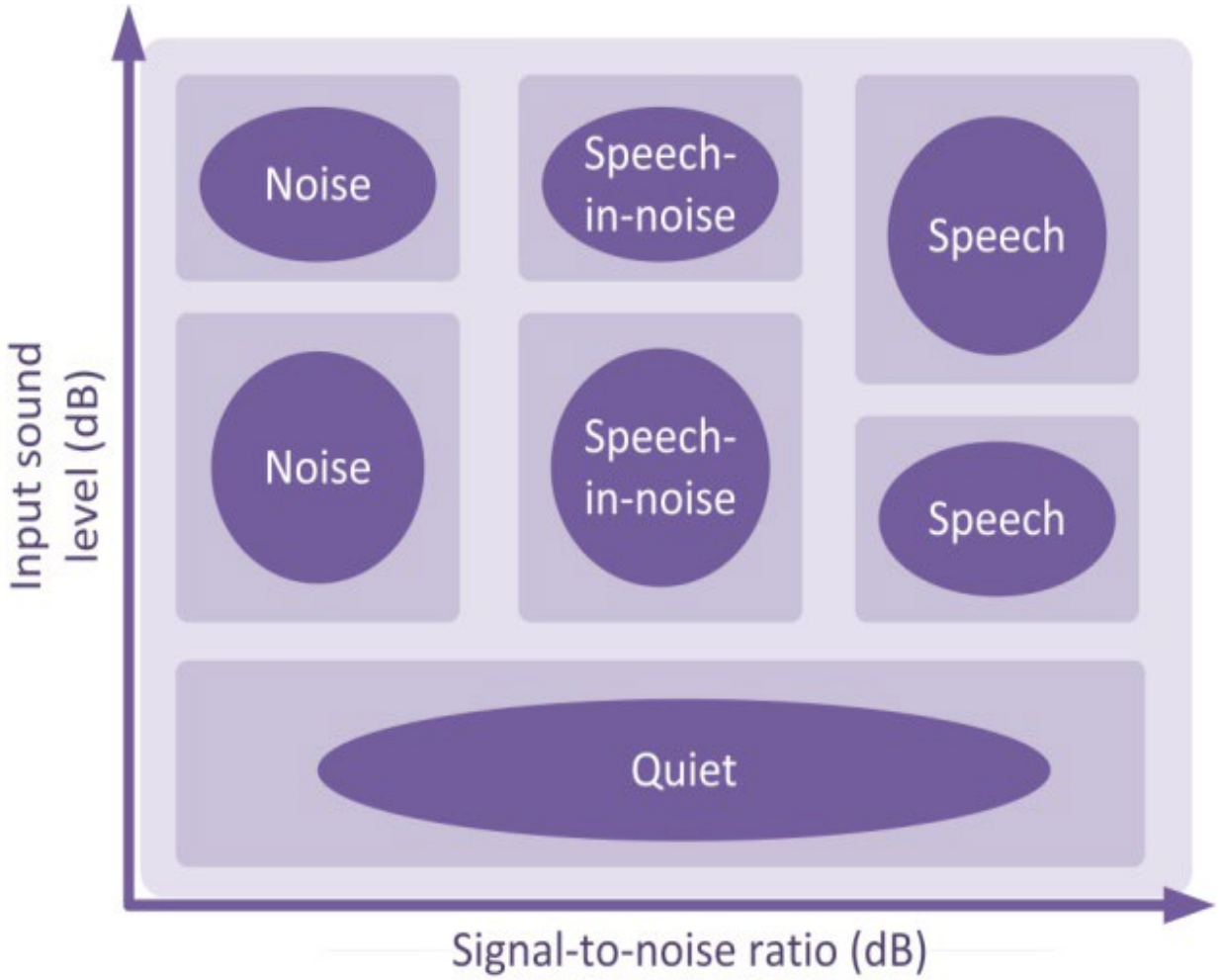
- How well does input signal match speech pattern?



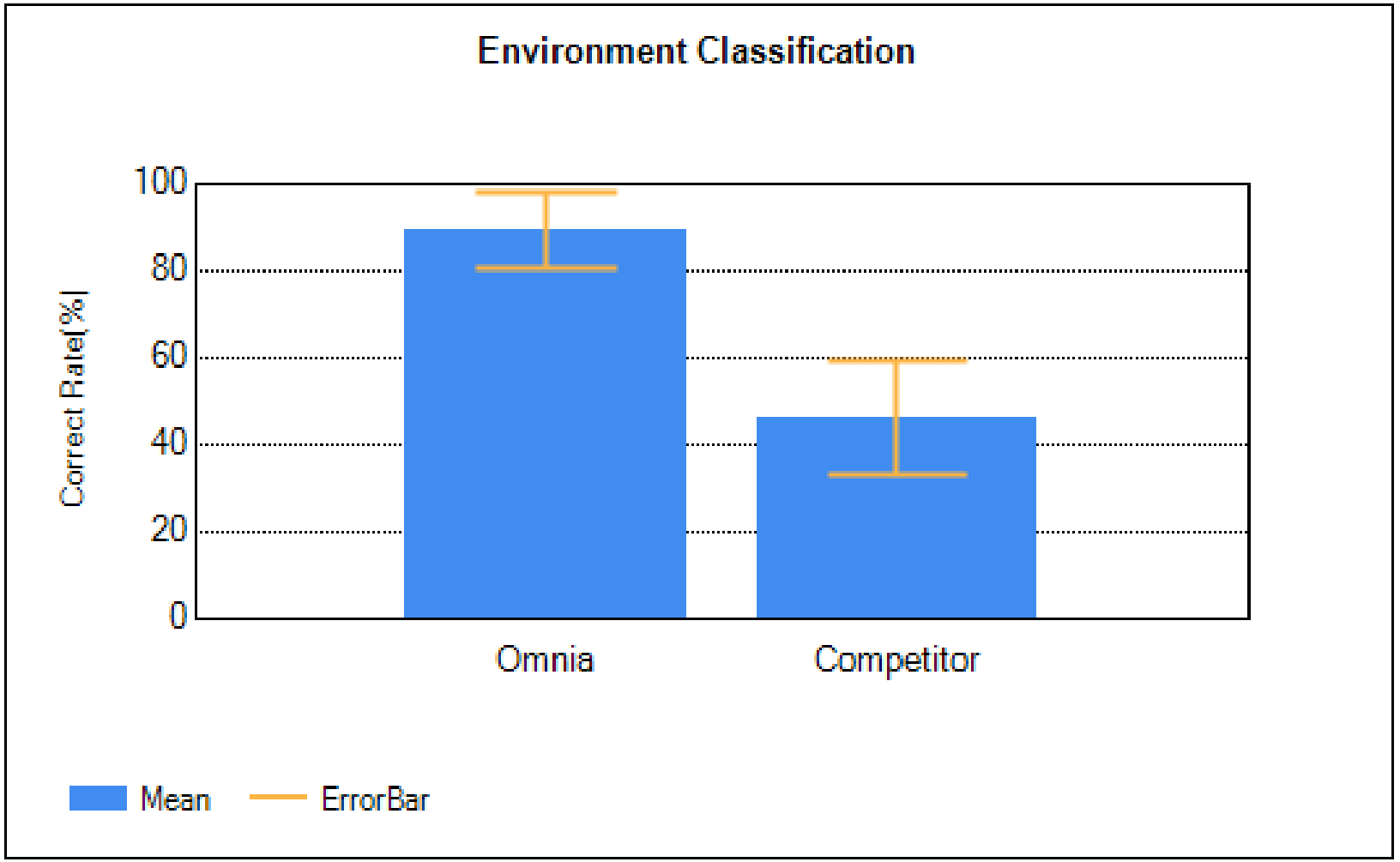
Speech detector

- Check spectral balance
- Check minimum signal duration and pause duration
- Check maximum signal duration
- Check high frequency repetition

Category determined by SNR and level



Environment Classifier Accuracy



Omnia Mean= 89.6%
Another Manufacturer Mean= 46.3%
Total Environments tested =11

Error Bar is Standard Error

Paired t-test
t = 3.2282 df = 10.000 p = 0.00905

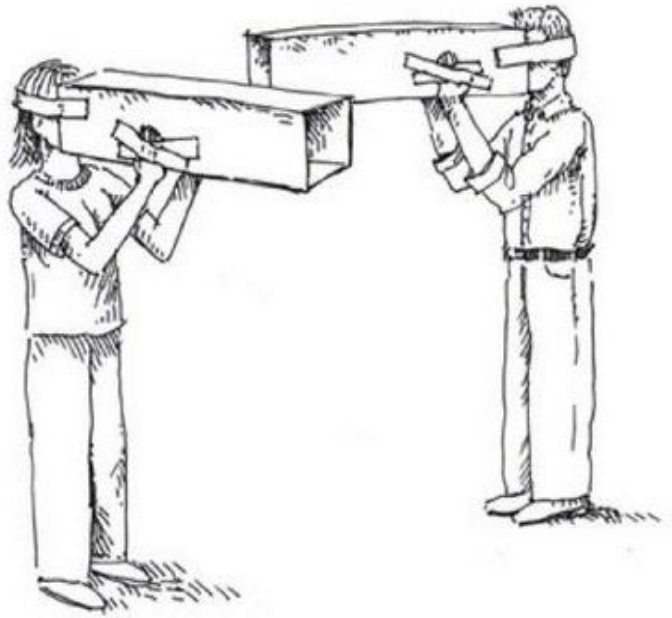
Environmental Classification

Once we established the accuracy of the environmental classification, we can confidently evaluate features.

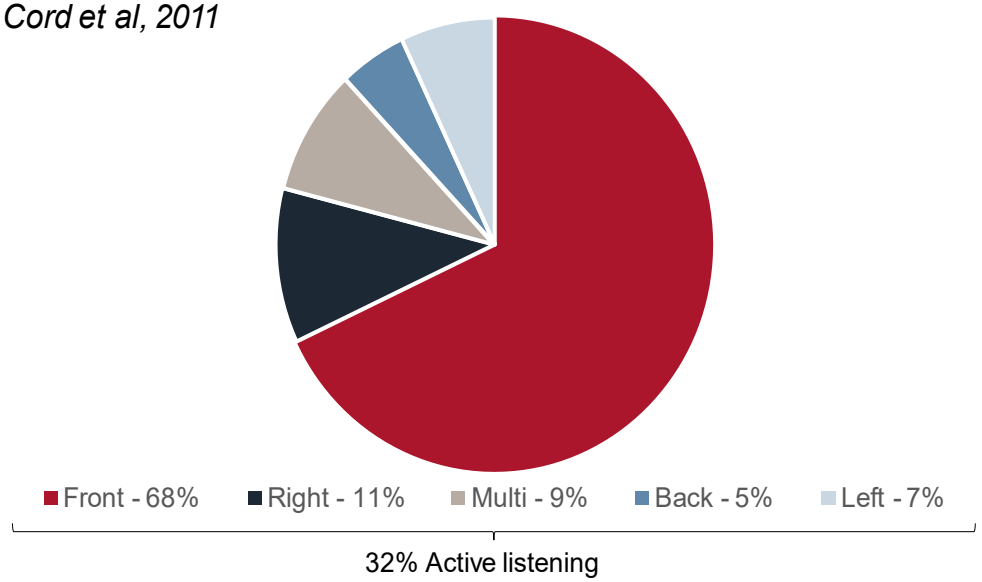
And, when it comes to hearing in noise, the primary hearing aid feature is…

Directionality

Overcoming the Limitations of Classic Directionality



Cord et al, 2011

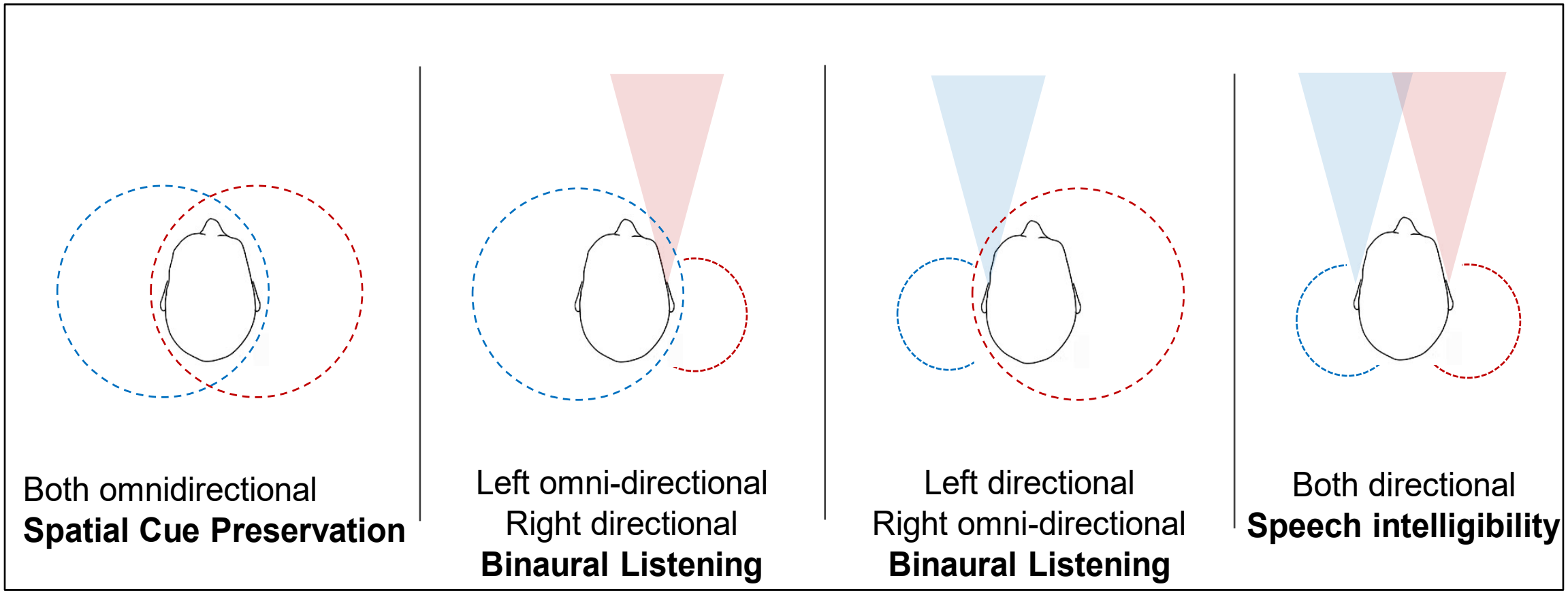


Percentual distribution of the signal of interest. Multi indicates that the direction of the signal was variable in this situation.

ReSound strategy

Individuals should make full use of their brain to determine the importance of the signal

Individuals should consciously choose the listening source



ReSound strategy for applying directionality

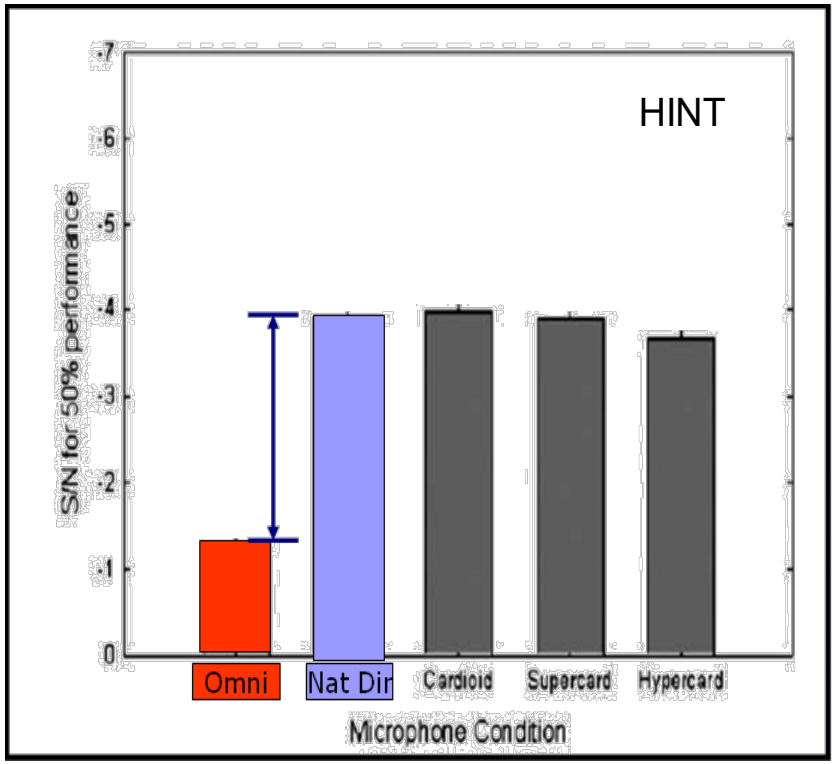
The ReSound strategy is to combine the strengths of technology with the strengths of the human.

The point is to make the hearing aids as useful as possible in the everyday lives of the user:

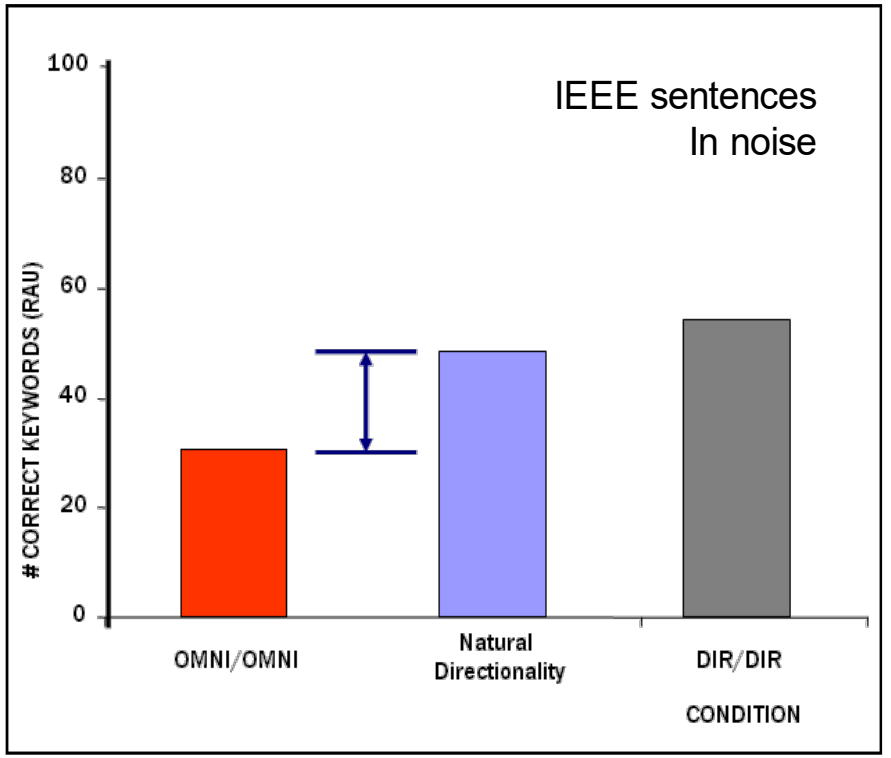
- Allow the brain to sift through information, focus on wanted sounds, and shift attention
- Do not interfere with the brain's job by limiting access to surroundings

Proof of concept – asymmetric directionality

Results on speech-in-noise tests



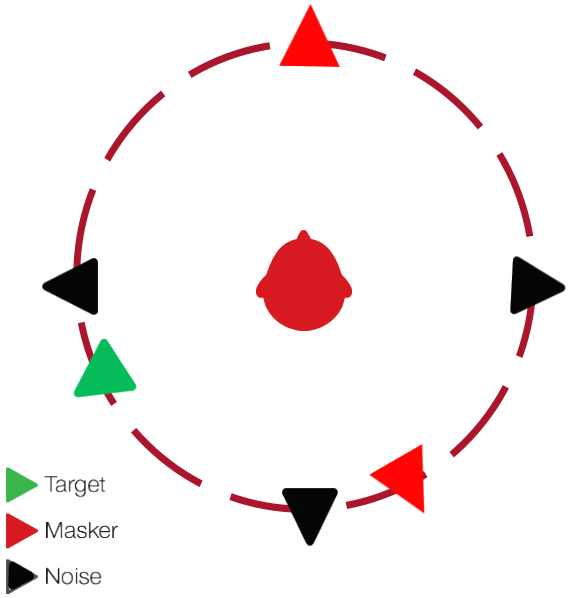
Bentler[1]

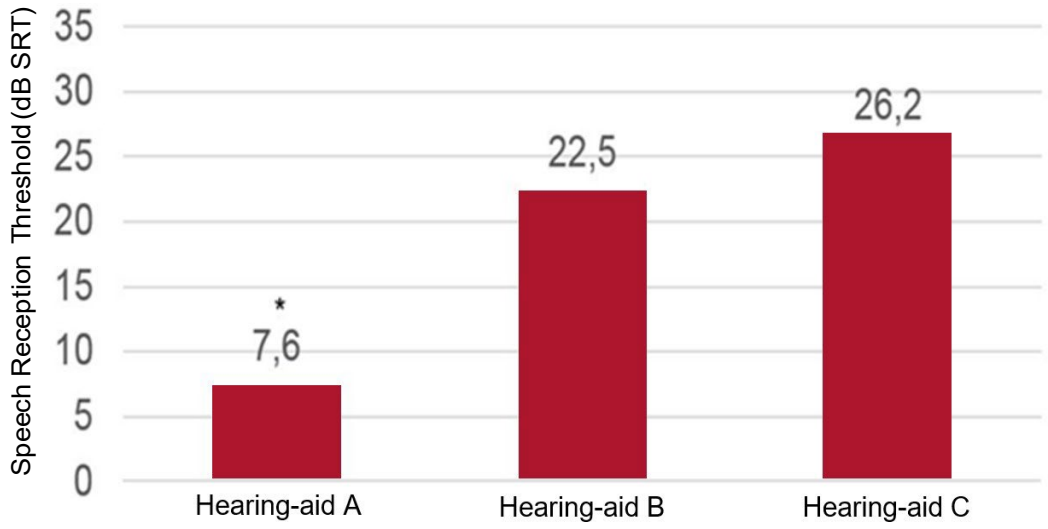


Walden[2]

1 Bentler et al, Journal of the American Academy of Audiology, 2004
2 Cord et al, Journal of the American Academy of Audiology, 2007

Hearing Outside the Directional Beam





Hearing aid A:

Fixed hypercardioid on right, omnidirectional on left

Hearing aid B:

Binaural beamforming

Hearing aid C:

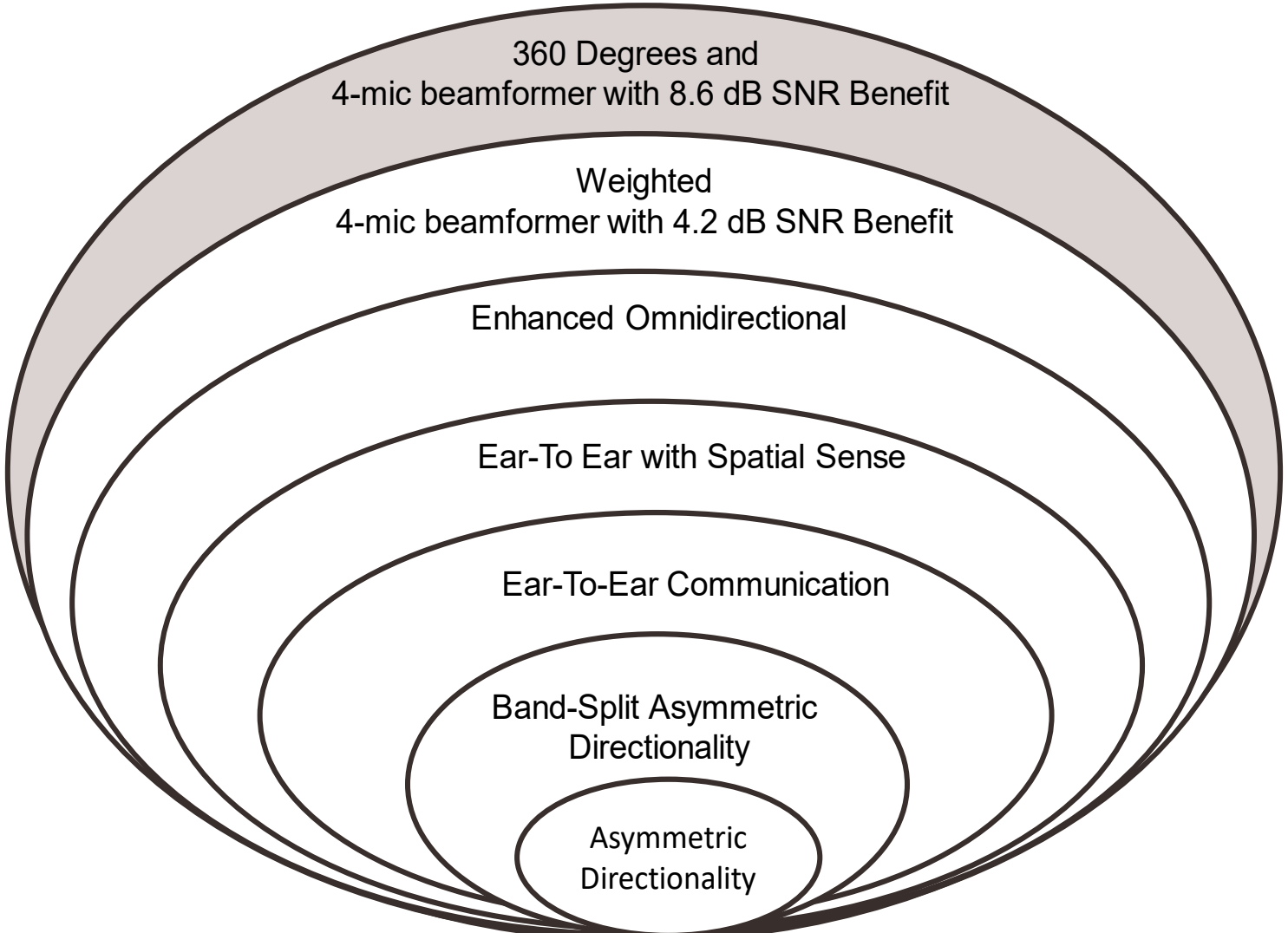
Binaural beamforming

** Lower values are best*

**Jespersen & Kirkwood 2016*

360 All-Around is our 7th generation of directionality providing directional benefit without being cut off from the rest of the environment

Omnia	360 All-Around
ONE	All Access Directionality
LiNX Quattro	Binaural Directionality III
LiNX², LiNX 3D	Binaural Directionality II
Verso, LiNX	Binaural Directionality
Alera, Live	Natural Directionality II
Azure	Natural Directionality



ReSound OMNIA

An incredible improvement in speech understanding*

15 experienced users

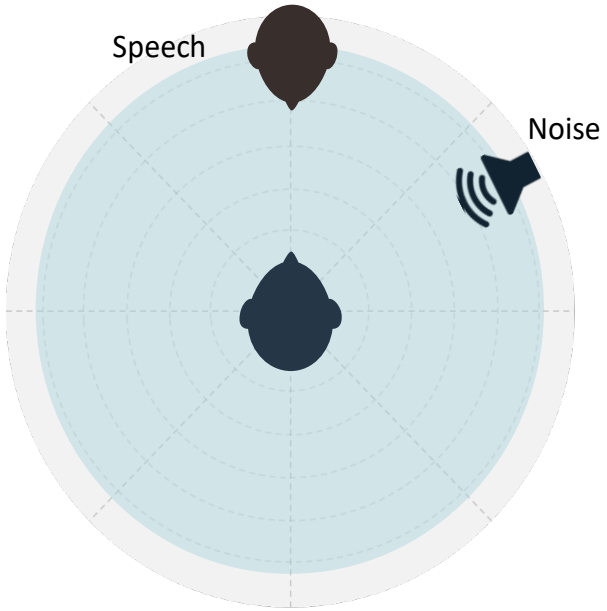
Mild-to-moderate HL

* Jespersen & Groth (2022)

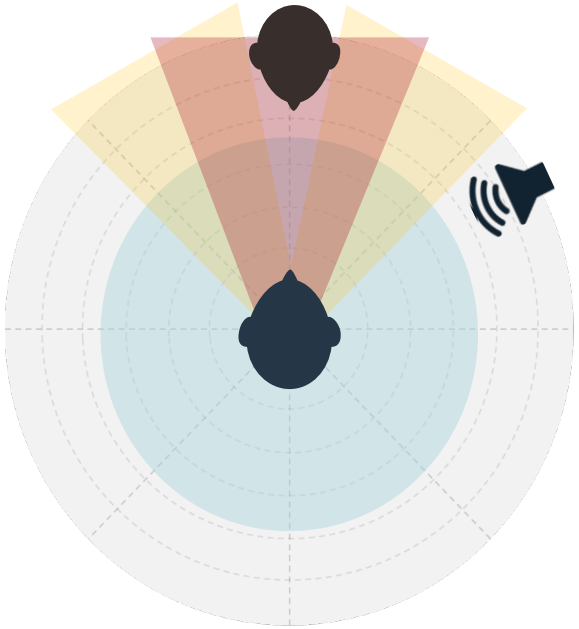
ReSound OMNIA

An incredible improvement in speech understanding*

Omnidirectional



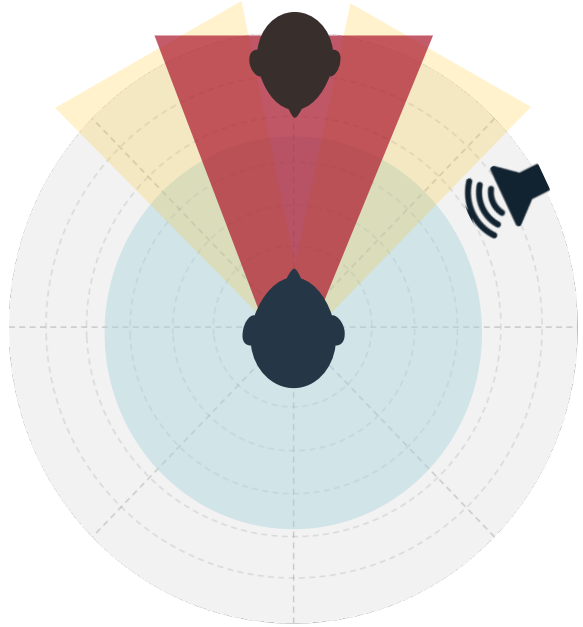
ReSound ONE with Ultra Focus



+4.2dB SNR

Better than omni

ReSound OMNIA with Front Focus



+8.6dB SNR

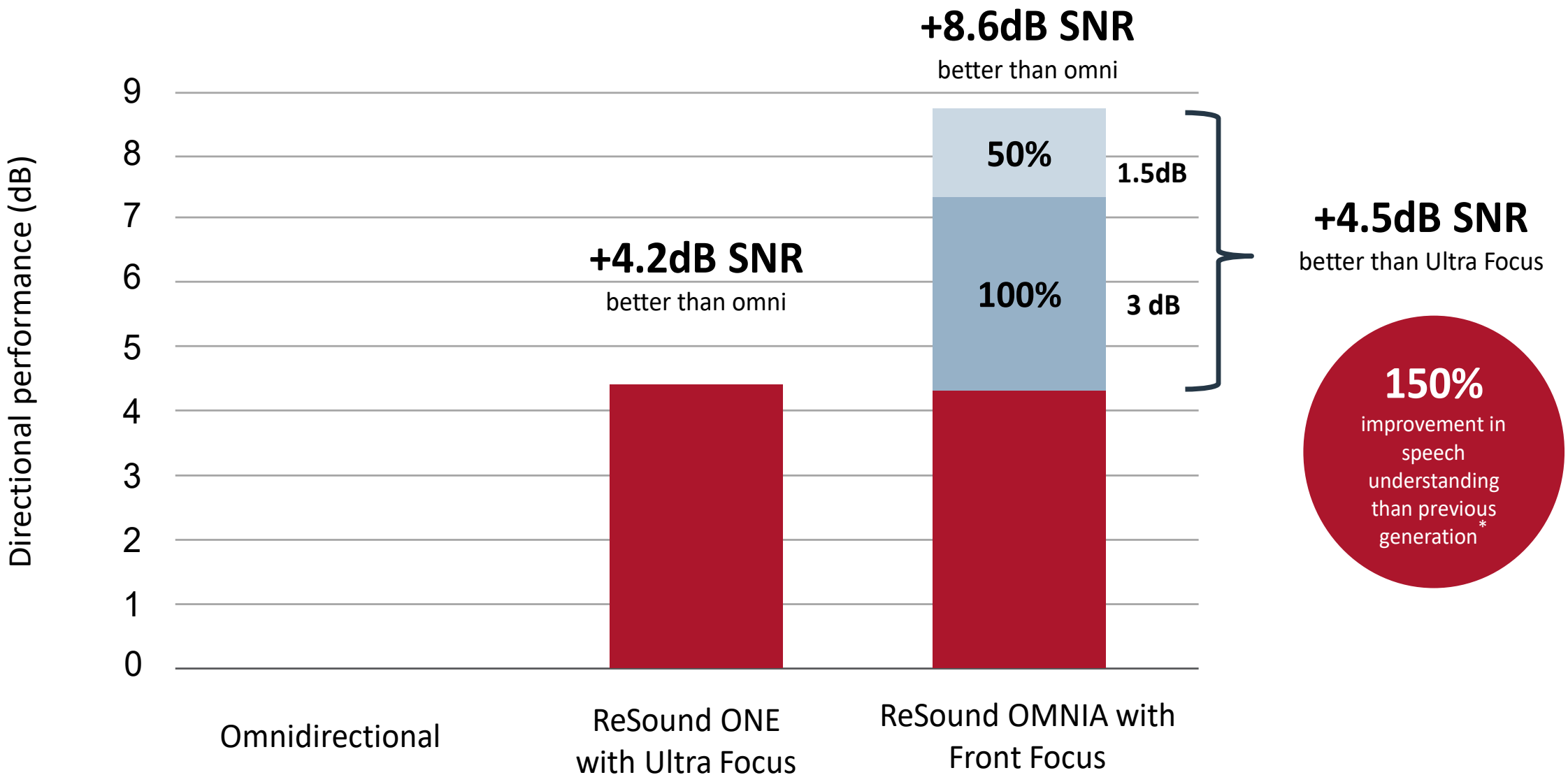
Better than omni

+4.5dB SNR

Better than Ultra Focus

ReSound OMNIA

An incredible improvement in speech understanding*



Directionality Measures

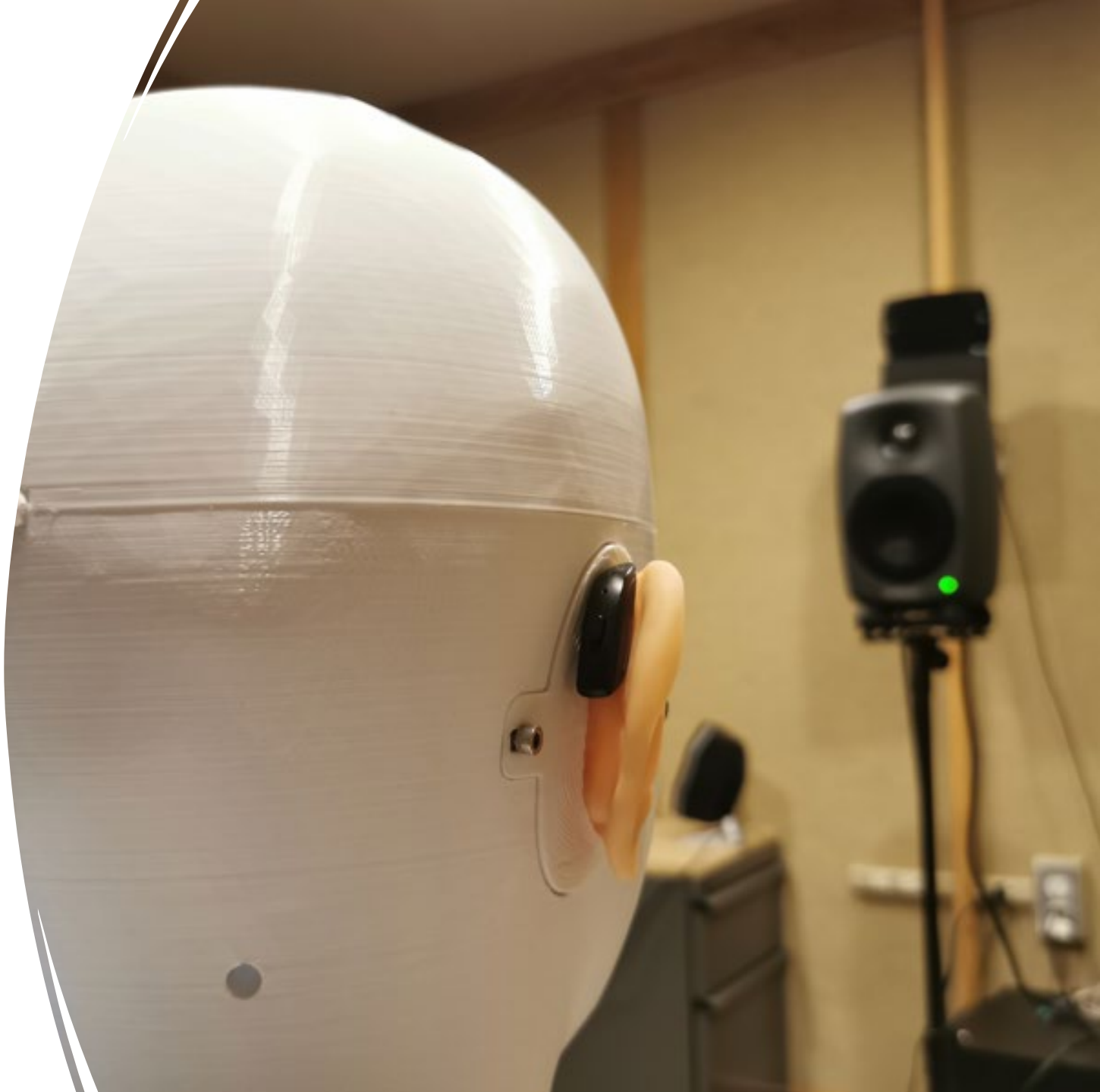
Programmed ReSound OMNIA and another manufacturer hearing aid with 2 programs

1. Omni Directional
2. Binaural Directional Beamforming

Presented white noise signal in sound booth

Continuously measured the directional pattern on an acoustic manikin by turning the manikin in a circle (360 degrees)

Measured the response for the right ear

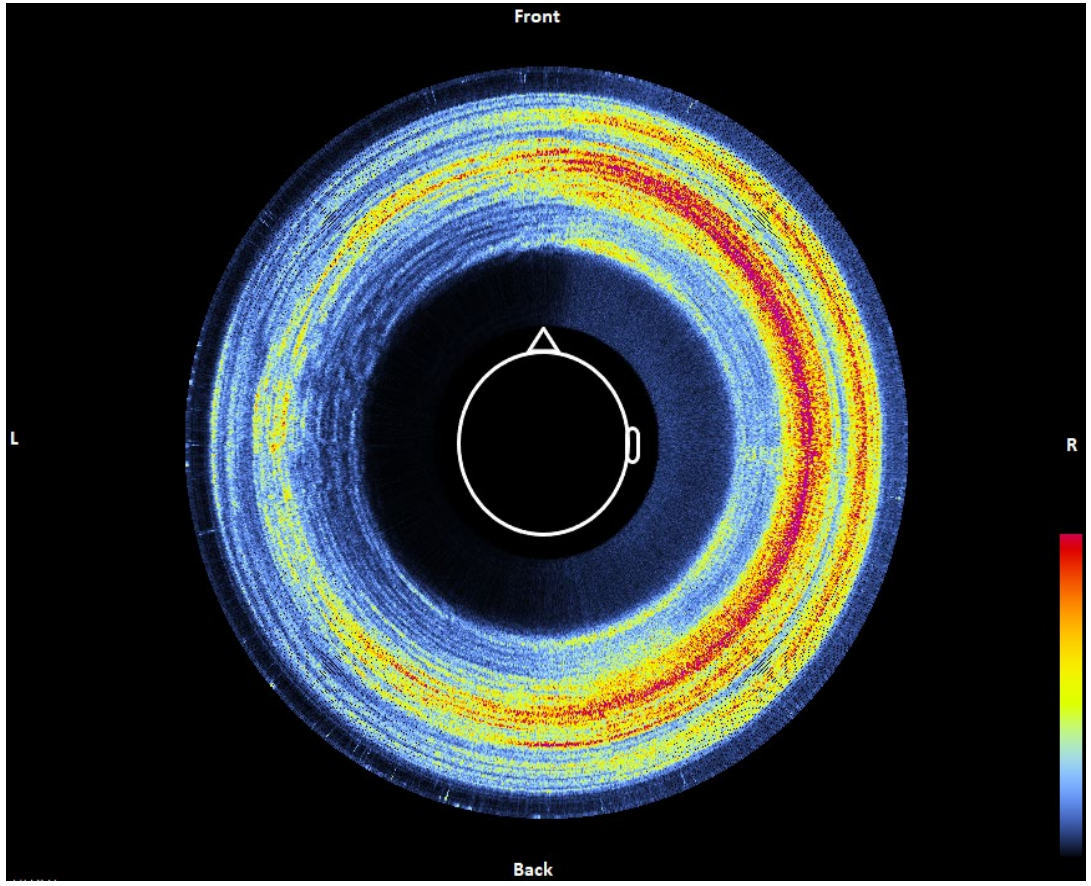


Quiet Environment

Center to edge of plot: High frequencies to low frequencies

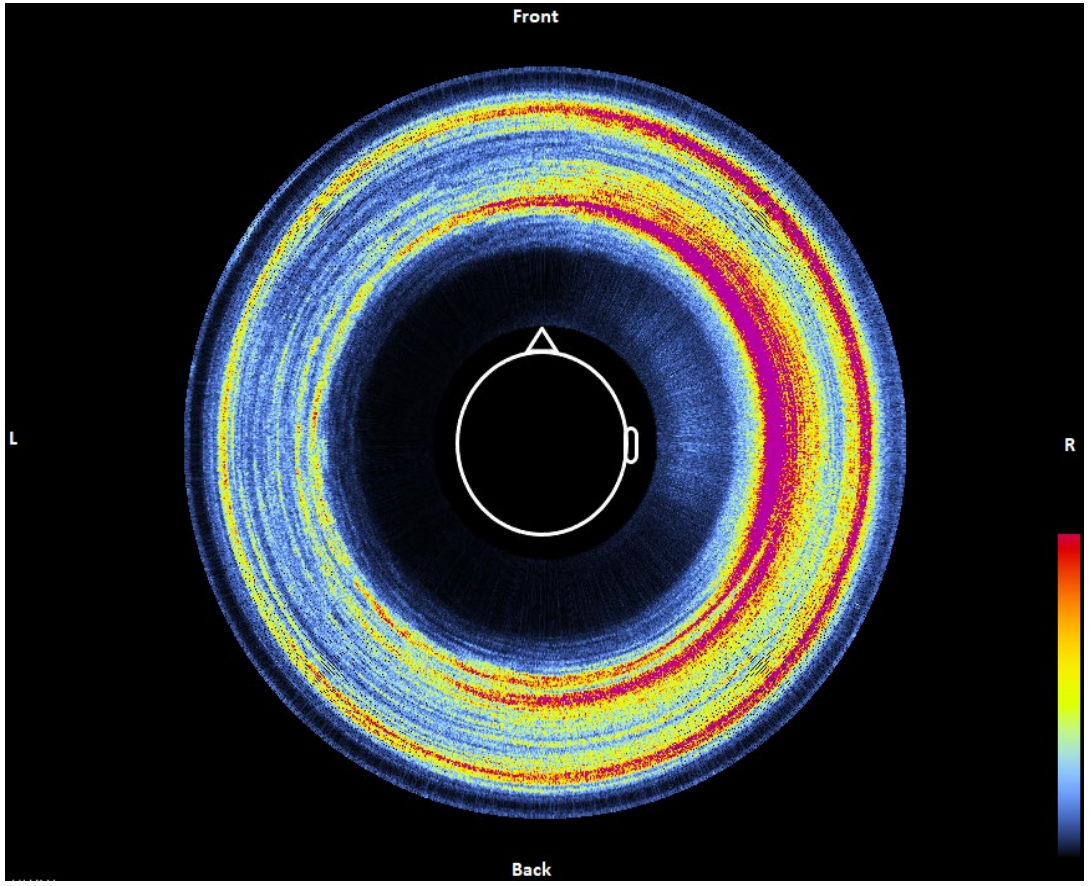
ReSound OMNIA

Omni directional



Another brand

Omni directional



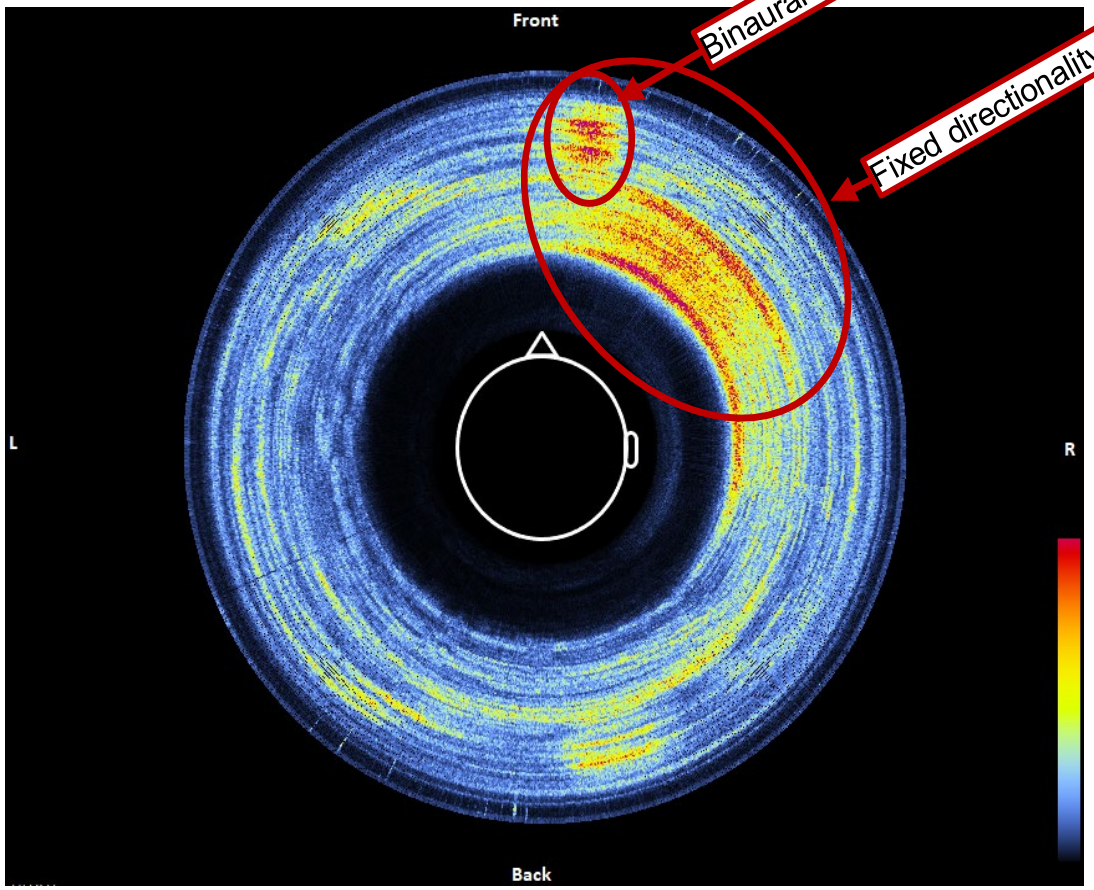
Note thinner audibility band due to restricted frequency response.

Directionality in Noisy Environment

Center to edge of plot: High frequencies to low frequencies

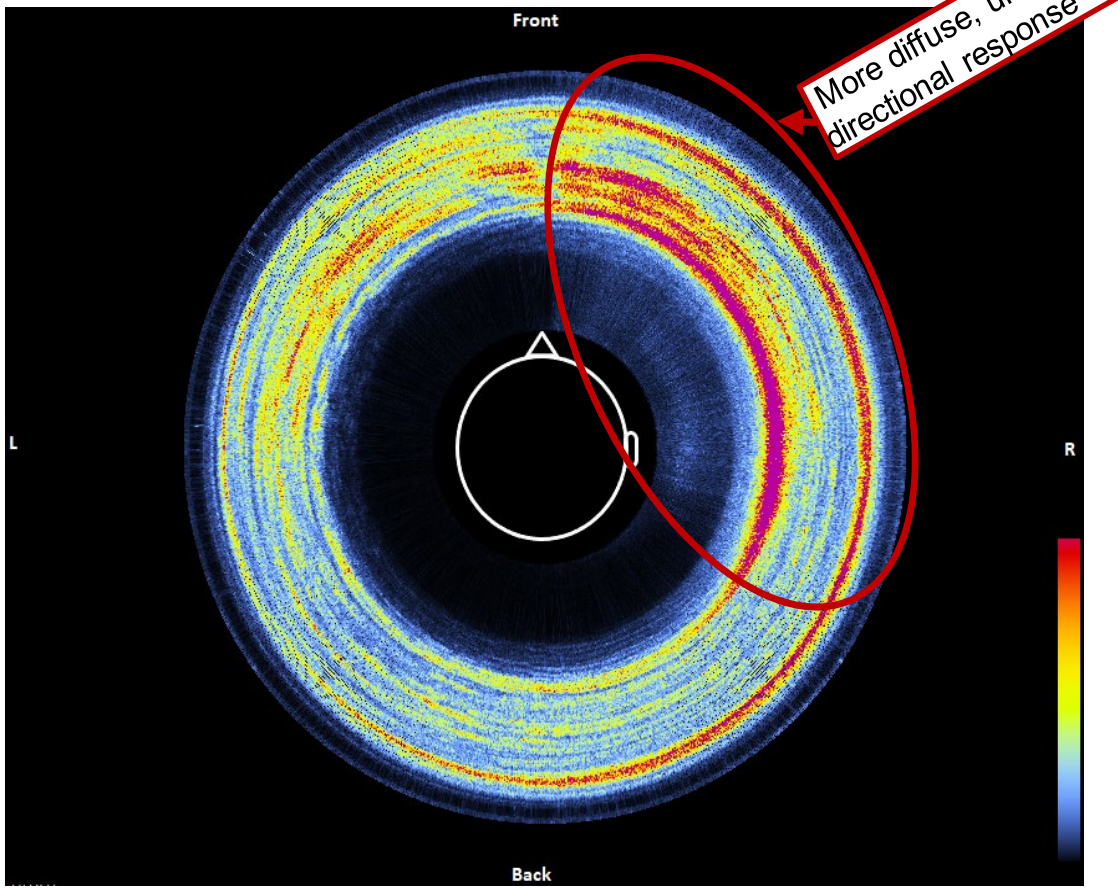
ReSound OMNIA

Front Focus



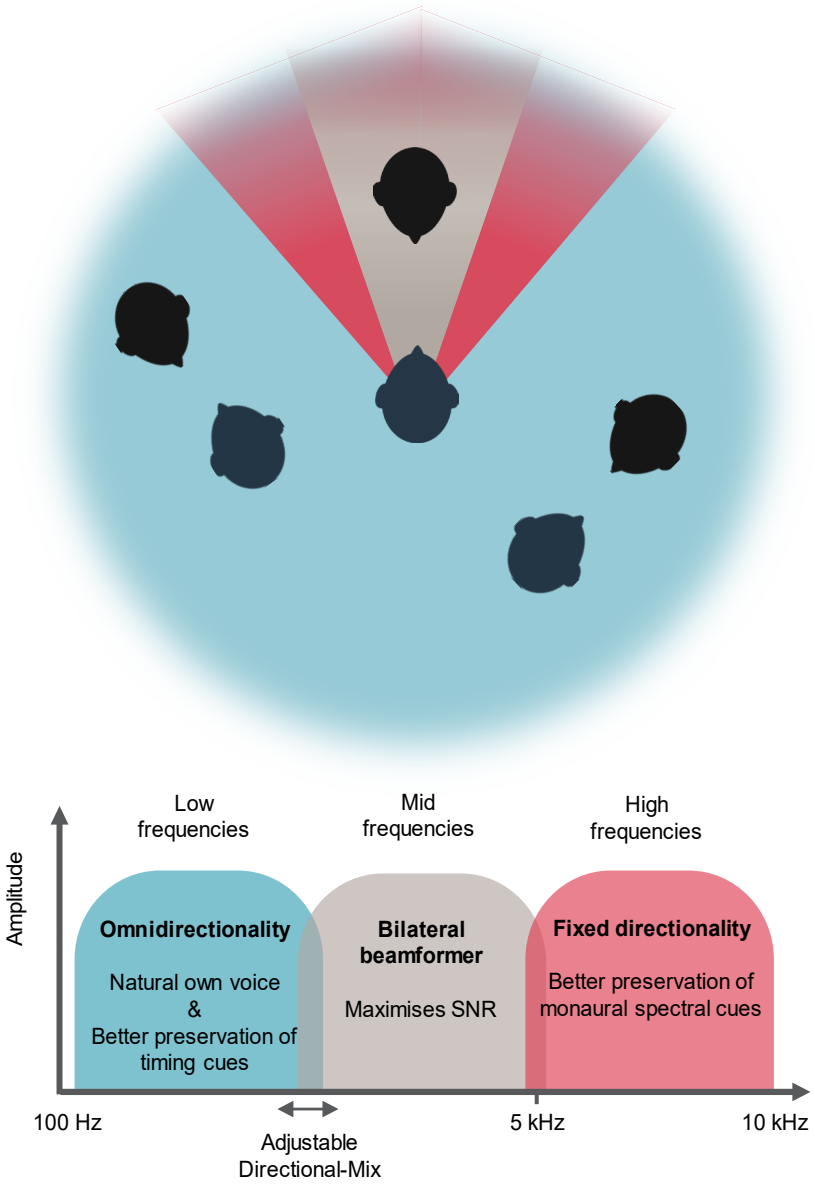
Another brand

Binaural beamforming directionality



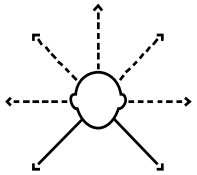
Note: more focused beamforming and multiband directionality!

Multi-bandsplit directionality

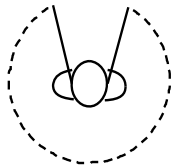


Designed so patients can enjoy the natural sound of their own voice even in background noise

Preserves natural own voice perception, naturally, without additional processing

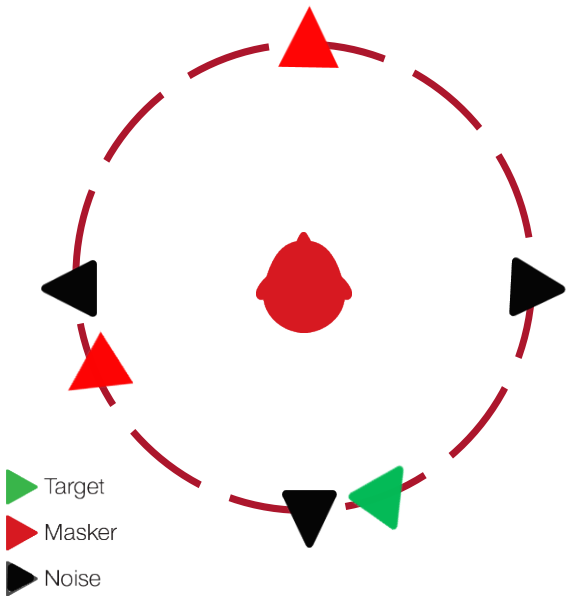


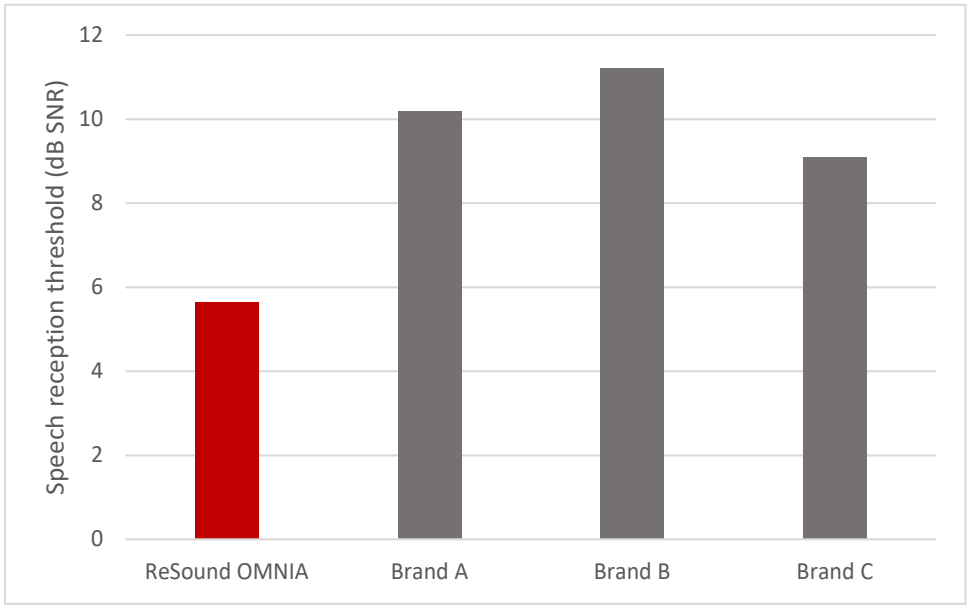
Maintains spatial awareness. Hear other conversations and details and in all directions.



Improves 1:1 hearing in the toughest environments

Hearing Outside the Directional Beam – 2023 update

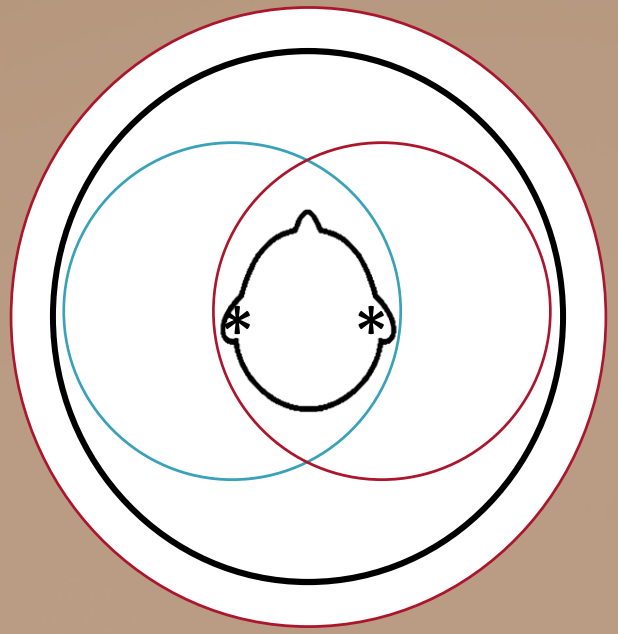




** Lower values are best*

Groth et al, 2023

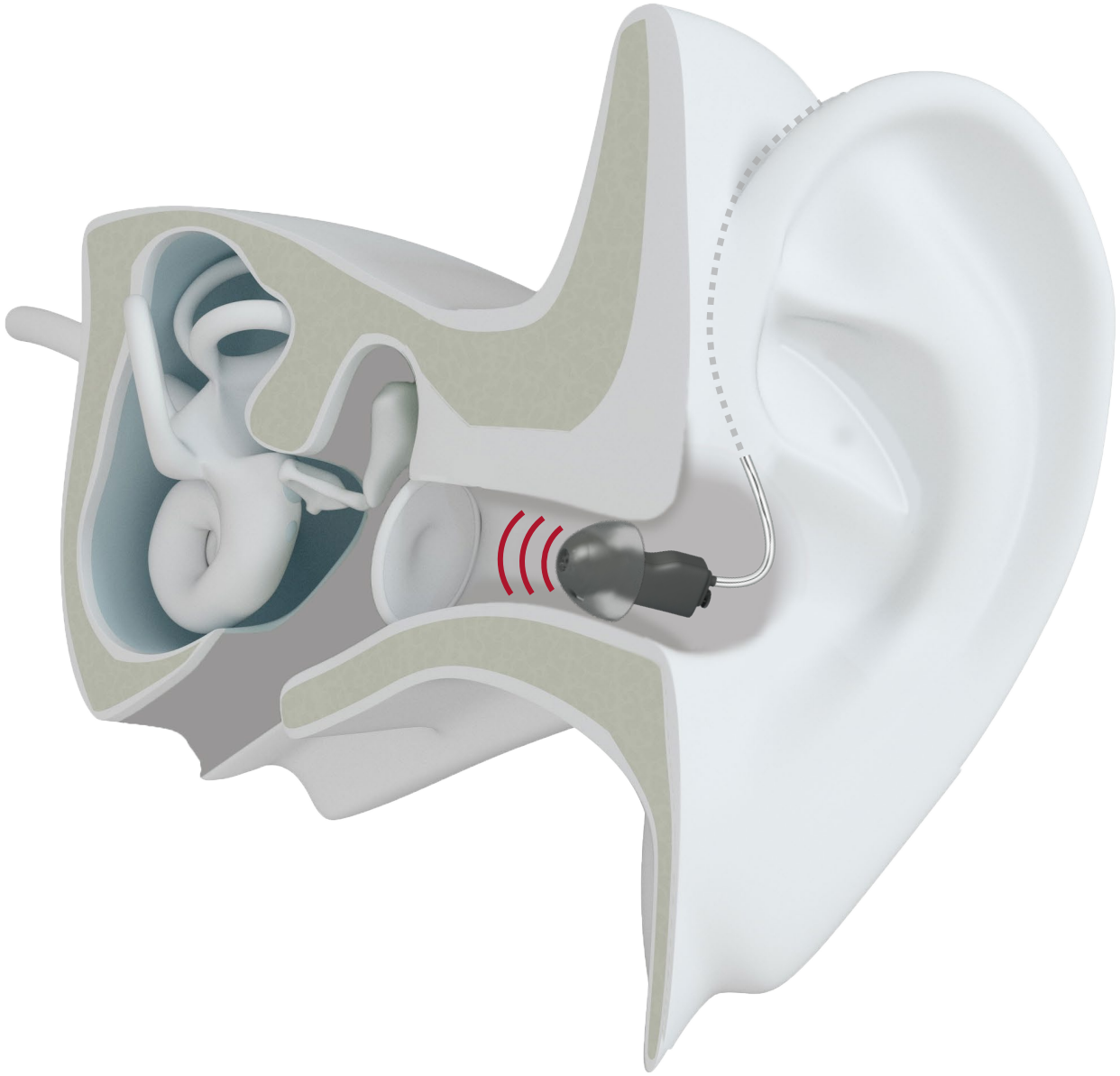
Spatial Cue Preservation



M&RIE
Microphone and Receiver-In-Ear

M&RIE is inspired by our organic hearing philosophy, combines the two on-device microphones with a third as an integrated part of the receiver module.

M&RIE & DFS Ultra III



M&RIE advantages and benefits

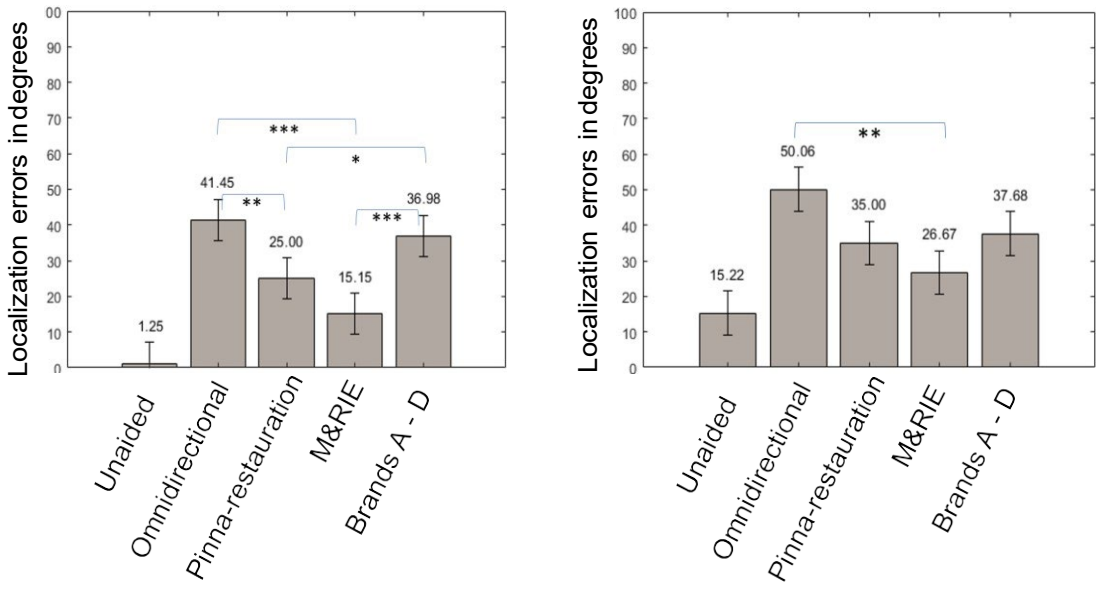
Improved localization

Natural sound quality

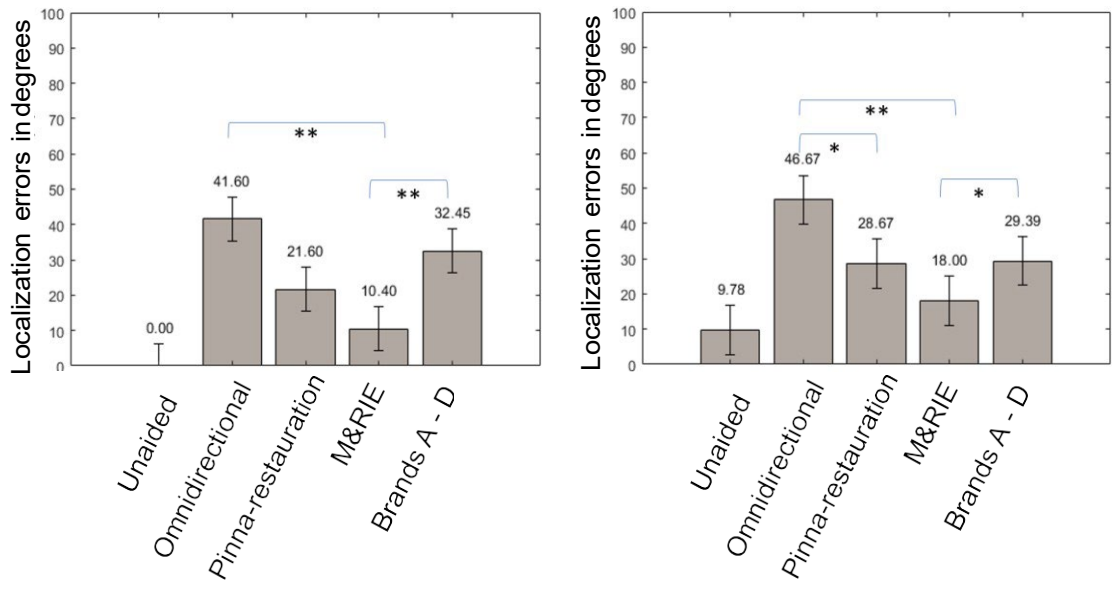
Comfort in wind

Improved localization

Listeners with normal hearing [1]



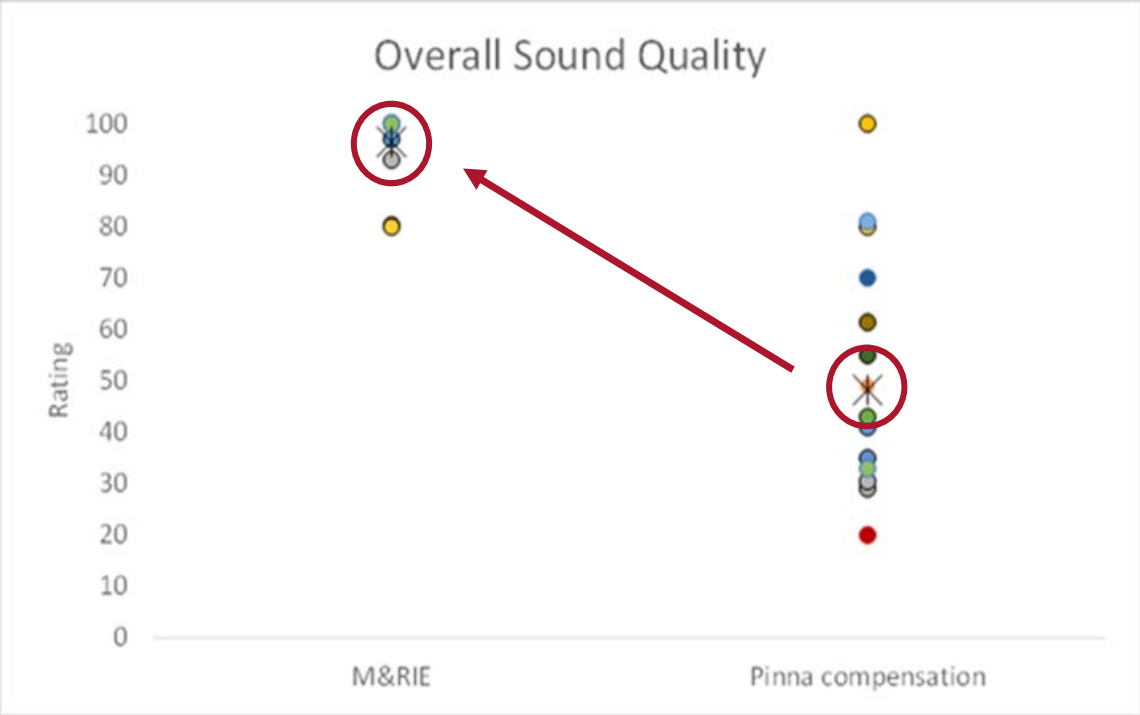
Listeners with hearing-loss [2]



*The asterisks indicate significant differences, with * indicating p <0.05; ** indicates p <0.01; *** indicates p <0.001.*

*Jespersen, Kirkwood, Schindwolf 2020

Natural sound quality



Comfort in wind

1. Measured wind noise objectively at varying azimuths and wind speeds in a wind tunnel to compare traditional mic placement with M&RIE
2. Field trial using EMA where HA users compared M&RIE with traditional mic placement in real-life

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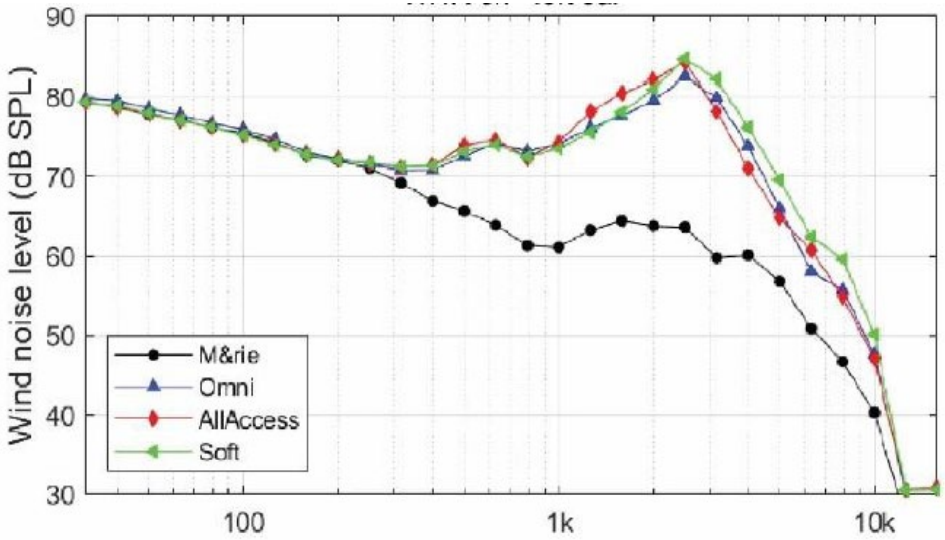


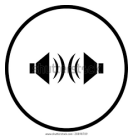
Results and conclusions

- Wind noise lower at all directions and orientations with M&RIE
- In the field, M&RIE preferred for enjoyment, wind noise, speech, and satisfaction
- M&RIE provides significant benefits in windy conditions and should be considered for all clients with mild to moderately severe hearing loss and an active outdoor lifestyle

Bluetooth Low Energy Audio and Auracast

What are the benefits of the Bluetooth technology ?

- It operates in the ISM band (2.3 – 2.4 GHz) that is available globally
- It is a cost-effective mainstream wireless technology – easy to install
- No interference from other electrical equipment



- Streams can be labelled to ensure that only the relevant signal is received
- Every modern hearing instrument has or will have it - giving more hearing instrument users the possibility for assistive listening

ReSound OMNIA ecosystem

Standardization for Bluetooth® Hearing Aids

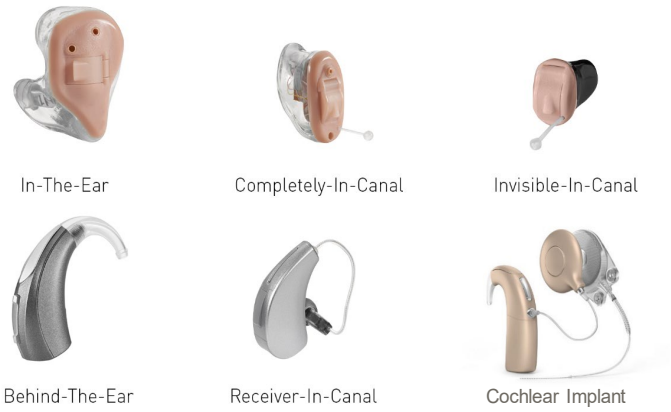
No audio specification for Bluetooth hearing instruments

Proprietary extensions to Bluetooth® technology

Mobile OS Programs: Apple MFi, Google ASHA

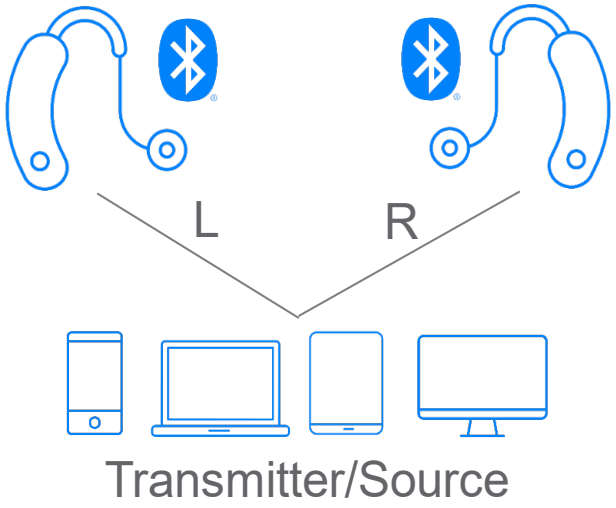
Variable handset and accessory interoperability

Limited selection



The Solution: Standardization

- New standardized profile for hearing aids (HAP)
- Better performance (quality, latency, power)
  - Low energy radio
  - New modern codec
  - Multi-streaming / binaural
- True, global interoperability
- More selection, choice, and accessibility



Bluetooth SIG, Inc.

Global trade association established in 1998

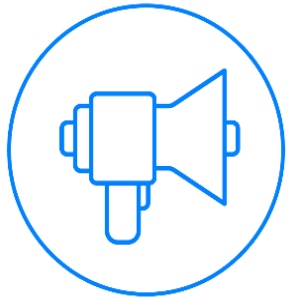
Oversees Bluetooth® technology and brand

Over 38,000 member companies in 150 countries

Over 5 billion devices shipped each year

Specification

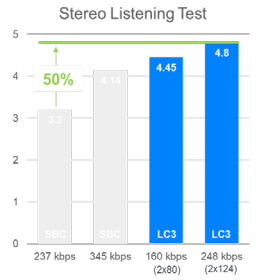
Qualification



Promotion

BTLE Audio | The next generation of Bluetooth® audio

New Modern Codec (LC3)



Higher Quality
Better Performance
Lower Power

Multi-Stream Support

Earbuds Standard
Binaural Hearing Aids
Seamless Voice Control

Standardized Hearing Aids

Better Performance
Lower Power
Global Interoperability

Broadcast Audio

AURACAST
A BLUETOOTH® TECHNOLOGY

Enhanced Listening
Next Generation Assistive Listening
(and more)

What is Auracast™ broadcast audio?

Auracast™ broadcast audio is a new Bluetooth® capability that will deliver great audio experiences for everyone - enhancing the way you engage with others and the world around you.

Share Your Audio

Shared listening and watching from your personal device

Hear Your Best

Public address and assistive listening

Unmute Your World

Public TV watching or immersive digital signage

Wide range of public location deployment options

Next-Gen Audio Accessibility

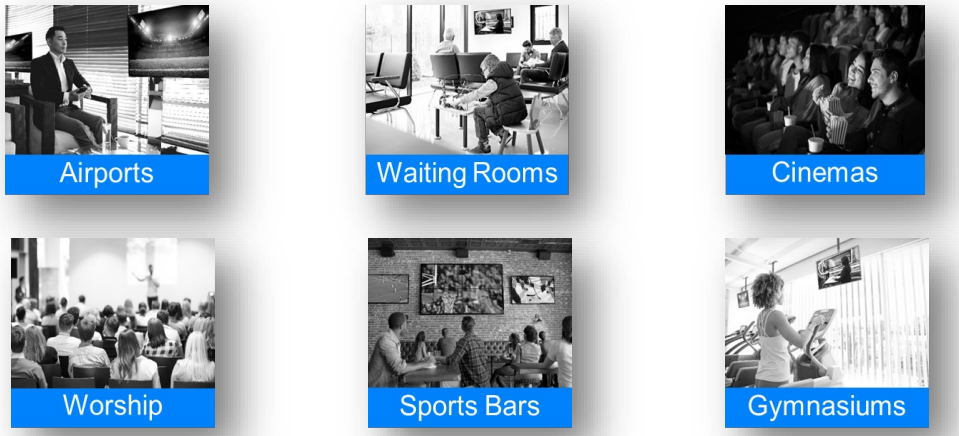
Ease of deployment – expands accessibility

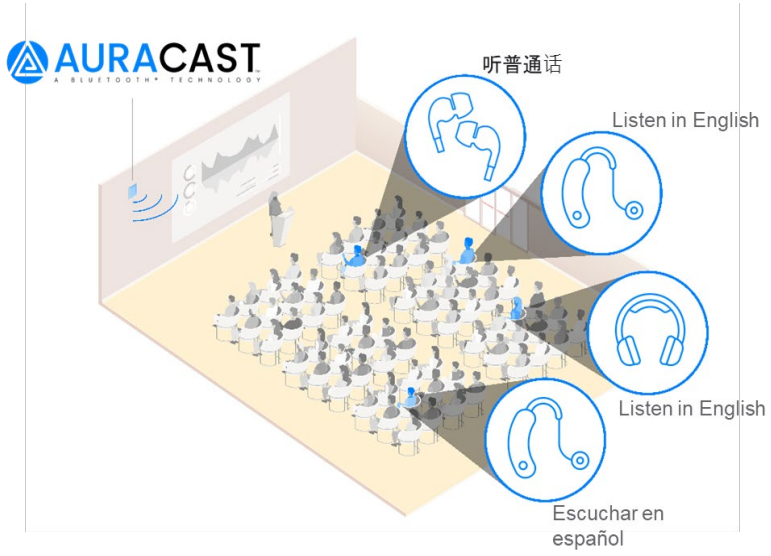
- Works alongside current hearing loop deployments

Improved user experience – increases satisfaction

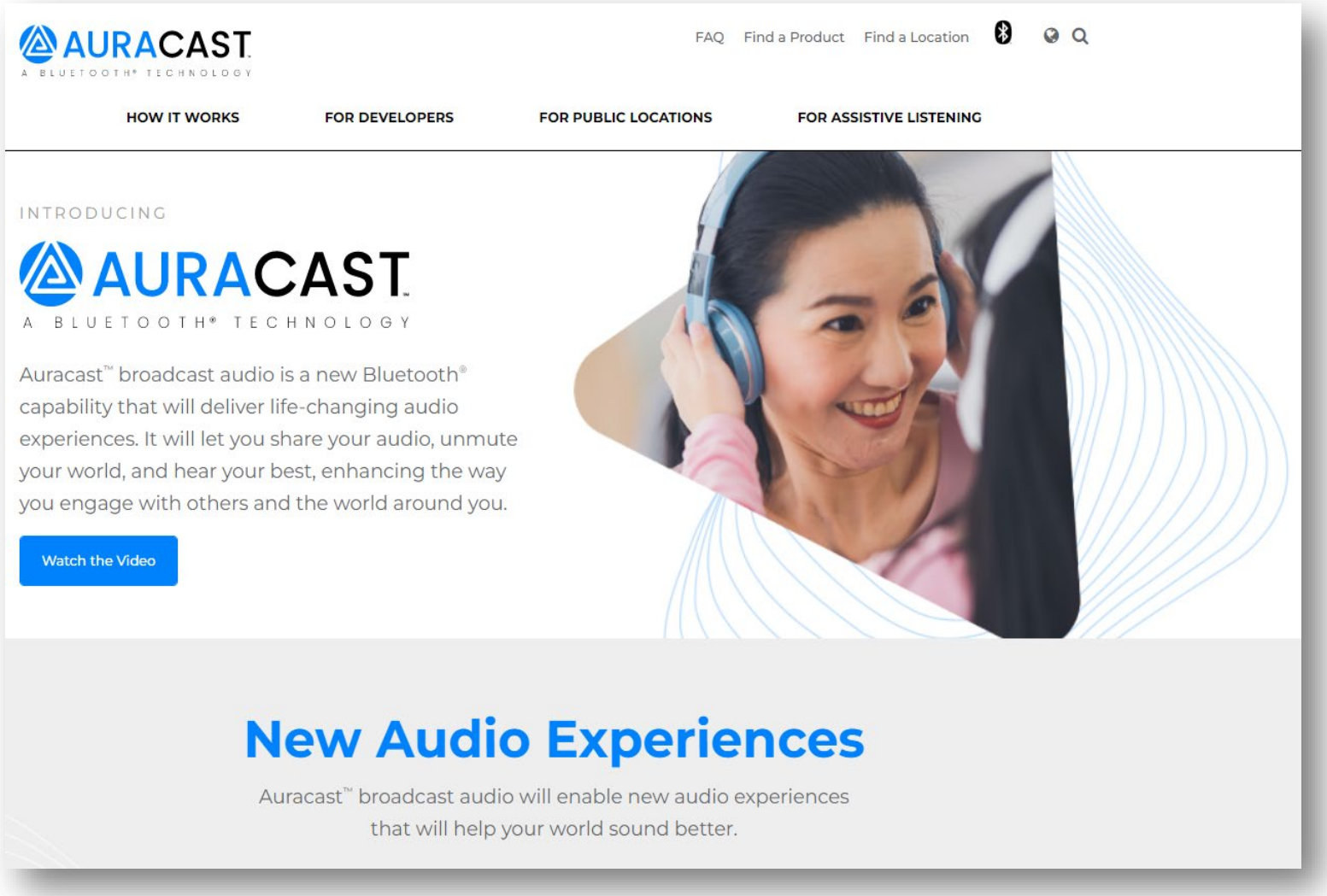
- Support broad demographic of users
- Multi-channel/multi-broadcast

Augmented audio – increases location value to more people





Auracast™ Information and Resources



Auracast™ General Information and Resources

- ❑ Education
- ❑ Research/Forecast notes
- ❑ Deployment guides
- ❑ Brand guides
- ❑ More to come

bluetooth.com/auracast

AI

Individual user needs & preferences

- Hearing aid users wear their hearing aids in a variety of acoustic environments.
- Individual preferences and needs are variable.
- Current solutions are based on simplistic assumptions that are challenged to handle real environments in real time to meet user needs
- AI provides more powerful and accurate set of tools that will be pervasive in hearing care

Artificial Intelligence: learning from data

Artificial Intelligence

Artificial intelligence (AI) describes the development and use of a computer system with the ability to perform some of the functions that are normally associated with human intelligence and discernment, such as learning, problem-solving, decision-making, and pattern recognition.

Machine Learning

Machine learning is a type of artificial intelligence that enables (trains) an algorithm to build a predictive model from input data and then applies that learning without the need for human intervention – to make useful predictions from new data.

Deep Learning

Deep learning is a Machine Learning method based on artificial neural networks that mimics the workings of the human brain in processing data. Deep learning can even happen without human supervision and draw from unstructured and unlabeled data.

Sensors in AI

Like sense organs in the human body, electronic sensors can play a vital role in AI. Sensor solutions are mostly responsible for data acquisition that is then transmitted and computed by a more capable network device.

Table 1. AI Chatbots in Hearing Health Care - Applications, Risks, and Research Priorities for Patients, Clinicians, and Researchers

Target Users	Potential Applications	Potential Risks	Research Priority Examples
Patients	Initial screening and recommendation of interventions	Inaccurate or misleading information	Efficacy of AI chatbots in providing accurate and reliable information to patients
	Education and support	Overreliance on chatbots for decision-making	Impact of AI chatbots on patient outcomes and satisfaction with care
	Reminders and follow-up communications	Loss of human touch and emotional support	Effectiveness of chatbots in improving adherence to treatment plans
	Teleaudiology services	Potential for technical issues or difficulties with communication	Feasibility and acceptability of teleaudiology services assisted by chatbots
Clinicians	Data collection and analysis	Loss of empathy and understanding in patient care	Integration of AI chatbots with existing health care systems
	Decision support	Misdiagnosis or delayed diagnosis due to chatbot errors	Evaluation of chatbot accuracy and reliability
	Patient triage and referral	Incomplete patient information leading to improper triage or referral	Feasibility and effectiveness of chatbots in improving patient triage and referral
Researchers	Data collection and analysis	Incomplete or inaccurate data collection	Development of standardized protocols for chatbot data collection
	Participant recruitment	Potential for selection bias in participant recruitment	Open source systems so that one can better judge how data are used
	Cognitive testing and assessment	Limitations of chatbots in capturing complex cognitive processes	Comparison of chatbot-assisted and traditional research methods
			Evaluation of the validity and reliability of chatbot-assisted cognitive testing and assessment

Swanepoel de Wet et al (2023)

Artificial Intelligence examples in ReSound hearing aids

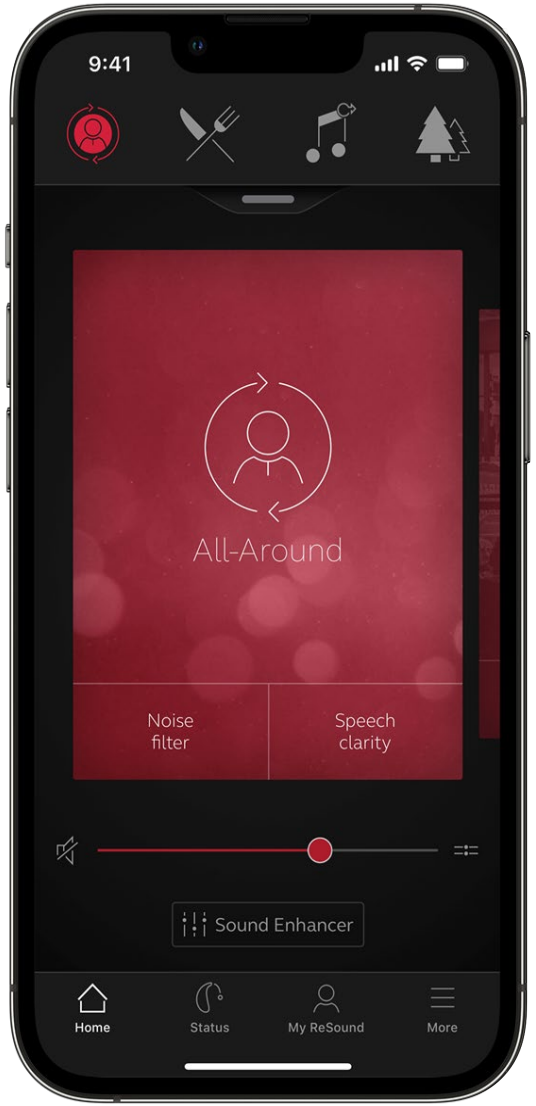
AI in our current solutions

- Since 2006 using machine learning to develop, design, and optimize our hearing aids and hearing solutions
- AI-based steering of our Digital Feedback System (DFS) to enable the unique microphone-and-receiver solution (M&RIE) that provides the most natural and individualized hearing experience
- AI enabling our directionality solution (360 All Around, Front Focus)
- Using AI simulation to optimize our antenna design in HI's
- AI enabled ear recognition and framing for Check My Fit in Smart 3D app

What we are working on

- Utilizing AI to optimize power consumption within small footprint / limited real estate hearing instrument designs
- Using AI to enhance steering algorithms
- AI enabled advanced noise cancellation

Check My Fit



ReSound Smart 3D with Check My Fit

Now compatible with all models

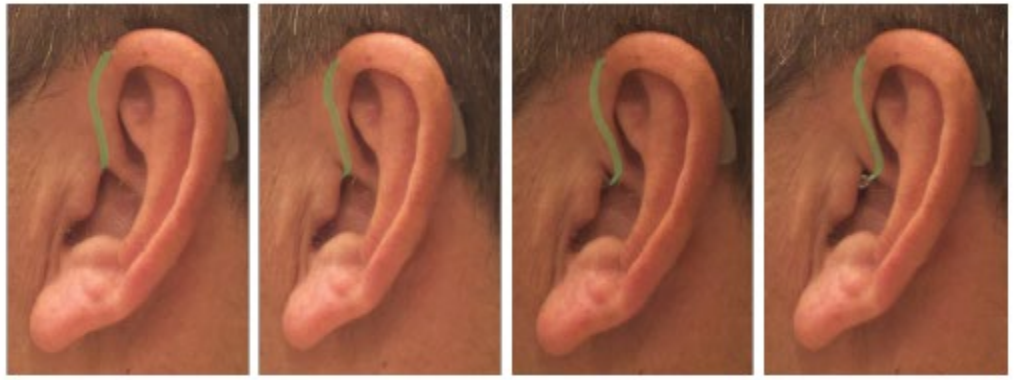
70% of users wear their hearing aids better with Check My Fit*

11dB of stable gain improvement*

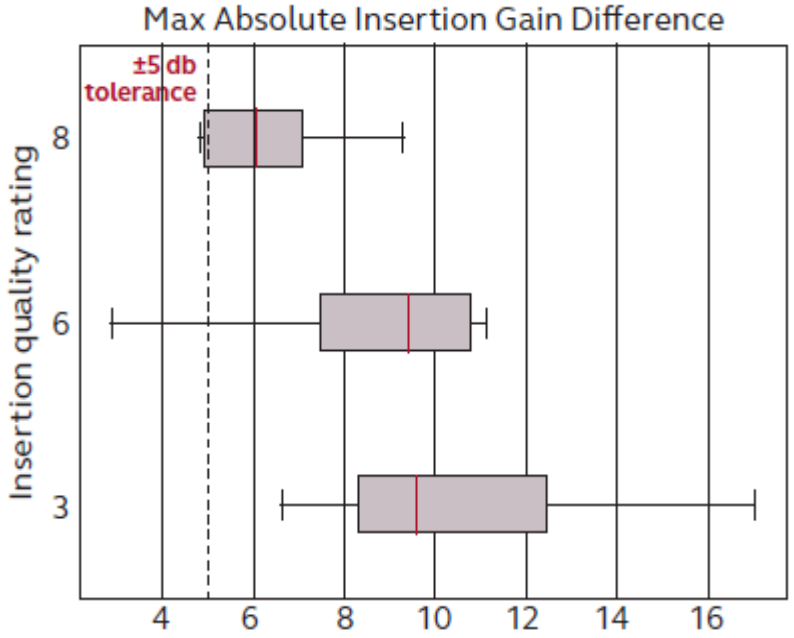
Compatible all hearing aid styles & legacy products

* Yang et al (2022)

Effect of insertion quality on real ear gain



Insertion Rating	10	8	6	3
Insertion Depth	12mm	9mm	5mm	4mm



Ear Detection – 87% accuracy

Dataset of 1000 images

Balanced by

- Skin tone
- Gender
- Age

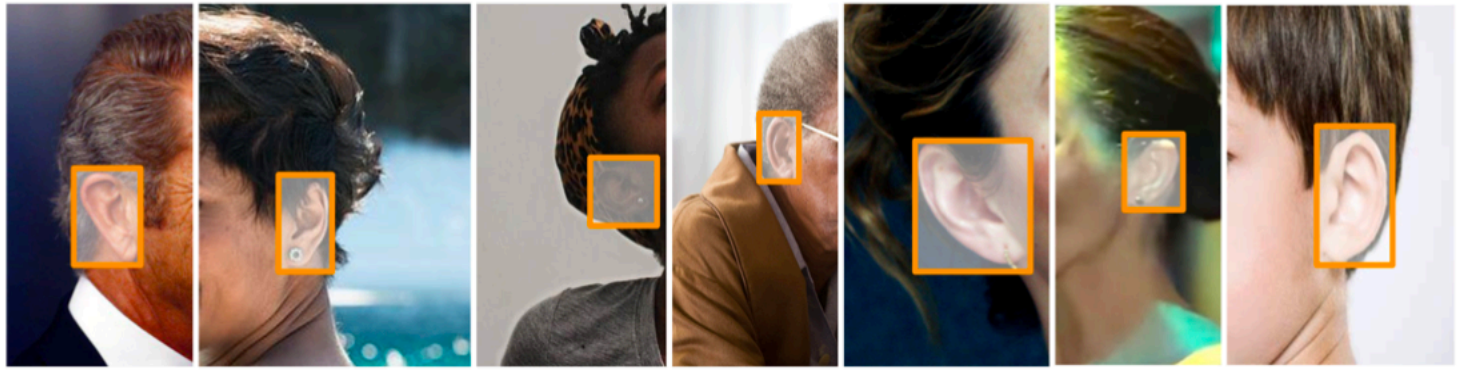


Fig. 4. Sample images from the public domain used for training the ear-detector.

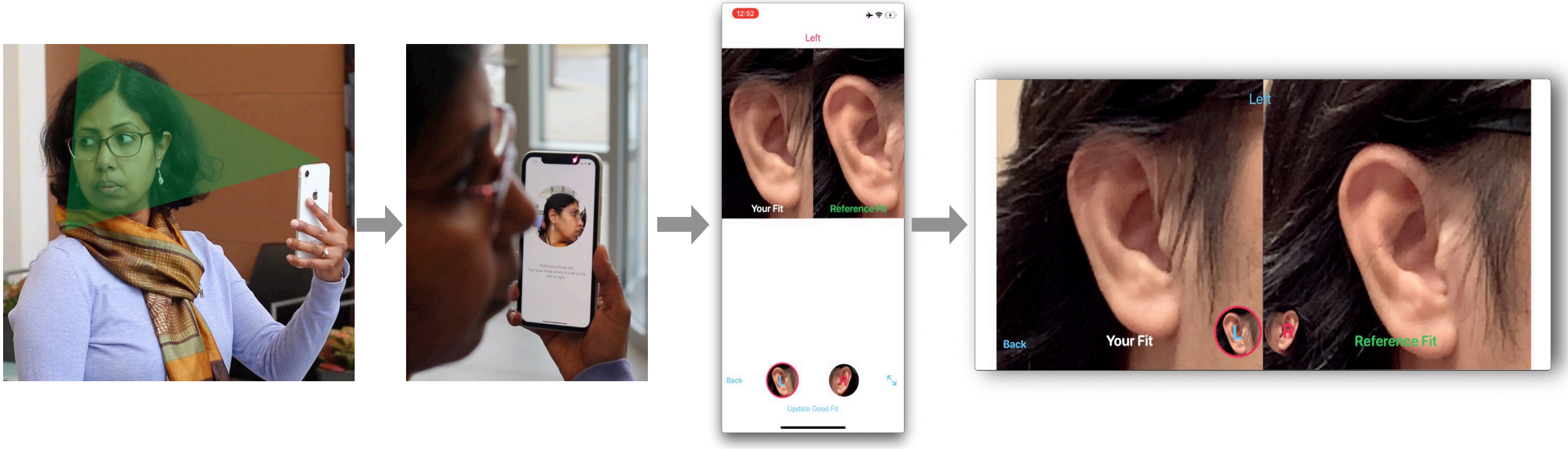
	Sex		Age		Skin Tone		Ear Side	
Training	Male:	528	<60 years:	818	Light:	705	Left:	453
	Female:	472	>60 years:	182	Dark:	295	Right:	527
	Total: 1000							
Testing	Male:	105	<60 years:	150	Light:	150	Left:	127
	Female:	150	>60 years:	105	Dark:	105	Right:	128
	Total: 255							

Table 1. Statistics of the ear-detector training and testing data sets. Light skin tone corresponds to Fitzpatrick scale Types I, II and III and dark skin tone to Types IV, V and VI.

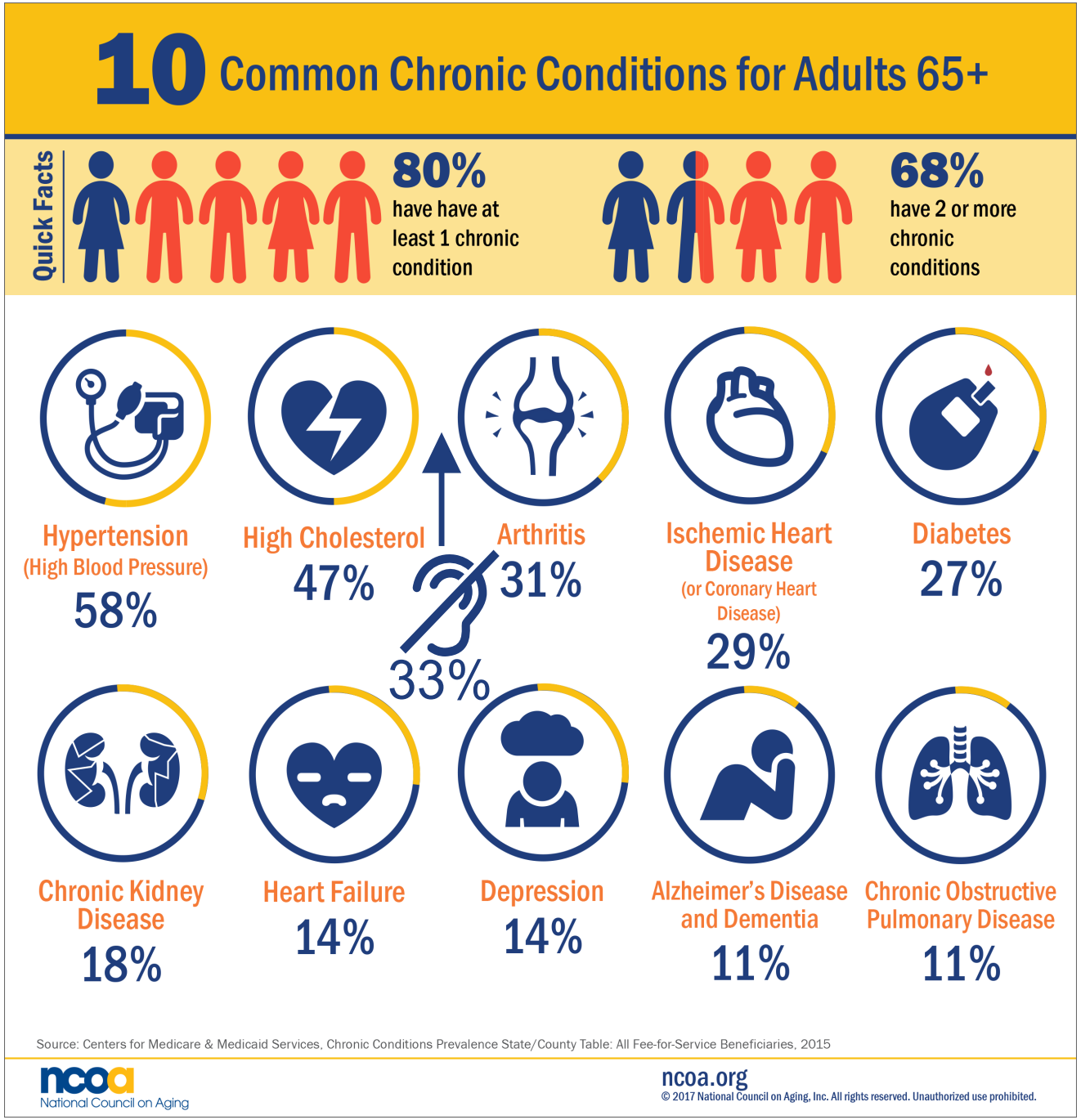
Fitting Mode

HCI Solution with Machine Learning (ML)

- *‘A picture is worth a thousand words’*
- Recognition vs Recall



Health



Source: NIH NIDCD (2018), NCOA (2017)

Where could sensors and hearing aids combine?

What can be measured in the ear?

- Temperature
- Heart Rate
- Oxygen Saturation in the Blood
- Respiratory Rate
    - From Which Stress and Fatigue Levels can be derived
- ECG
- Blood Pressure
- Blood Glucose
- EEG

Take-home messages

- Professional hearing care has major impact on outcomes with any hearing aids
- People who seek hearing help are largely driven by difficulties hearing in noise
- Apart from amplification, hardware and functional features such as VC, rechargeability and streaming are easily recognizable and highly valued by hearing aid users
- Automatic control features are as important as the sound processing features they turn on and off
- AI can be expected to affect all areas of hearing care in the future


ReSound GN