Enhancing Human Auditory Function with Artificial Intelligence and Hearing Aids

Dave Fabry, Ph.D. Chief Hearing Health Officer

HEARING
HEALTH & TECHNOLOGY MATTERS

Starkey

Disclosures

Full-time employee and Officer of Starkey

Cochlear Implant Advisory Board Member

Learning Outcomes

As a result of this course, participants will be able to:

1 Describe three ways that hearing aids use Artificial Intelligence (AI) today
2 Explain the difference between machine learning and deep neural networks
3 Identify three opportunities and limitations of AI use in hearing aid technology

HEARING HEALTH & TECHNOLOGY MATTERS

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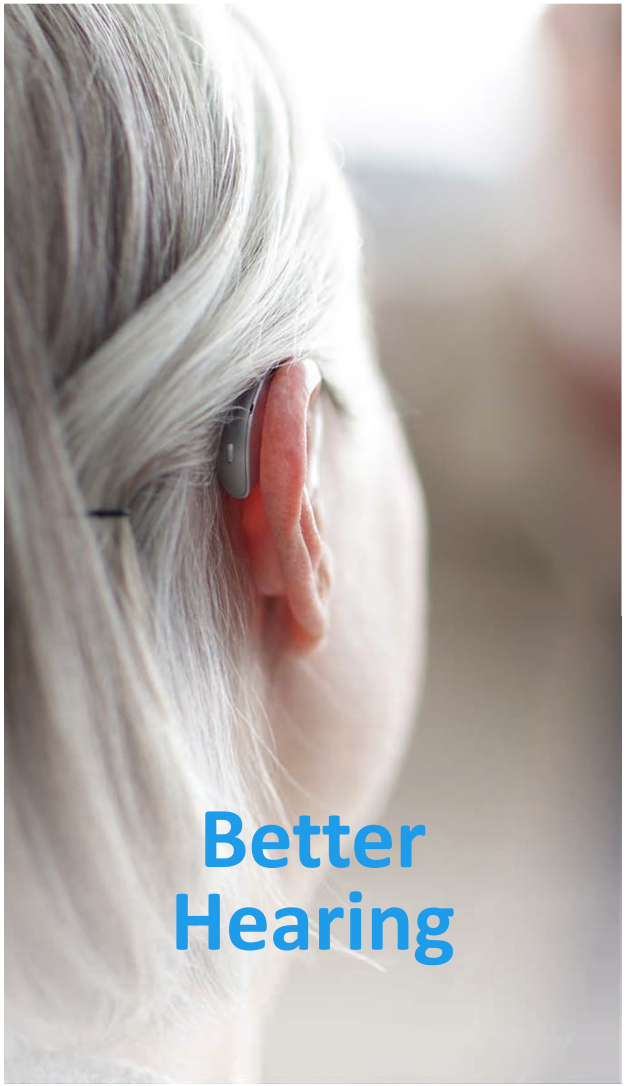
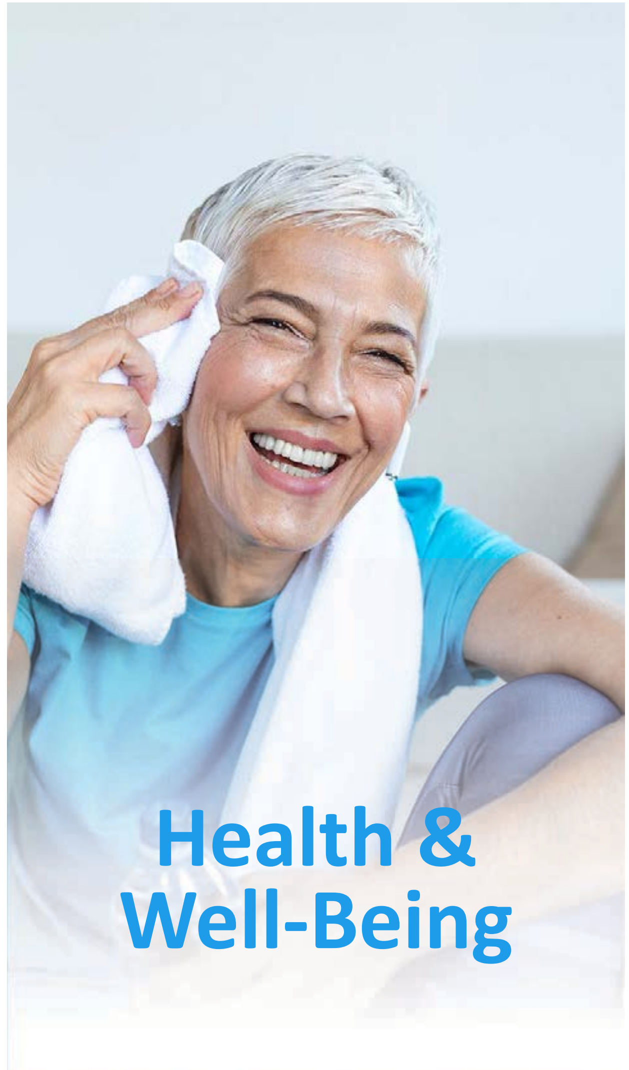

Better
Hearing


Health &
Well-Being


Virtual
Assistant

Top Drivers

of Hearing Aid
Performance and Sound

Natural Sounding
Rich and Clear

Comfort for loud sounds

Minimize background noise

Ability to tell direction

MarkeTrak 10 / Hearing Industries Association, 2019

Hearing Aid Satisfaction

85% Satisfaction with ***physical aspects*** of hearing aids (fit, comfort, size, appearance, reliability, etc.)

81% Satisfaction with ***sound quality*** of hearing aids (noise reduction, naturalness, clarity, feedback, etc.)

Least satisfied with noise reduction capability (**77%**)

Picou EM. Hearing Aid Benefit and Satisfaction Results from the MarkeTrak 2022 Survey: Importance of Features and Hearing Care Professionals. Semin Hear. 2022 Dec 1;43(4):301-316.

Understanding speech in difficult listening environments remains a challenge for hearing aid users

Percent of hearing aid owners satisfied with ability to hear in each listening situation

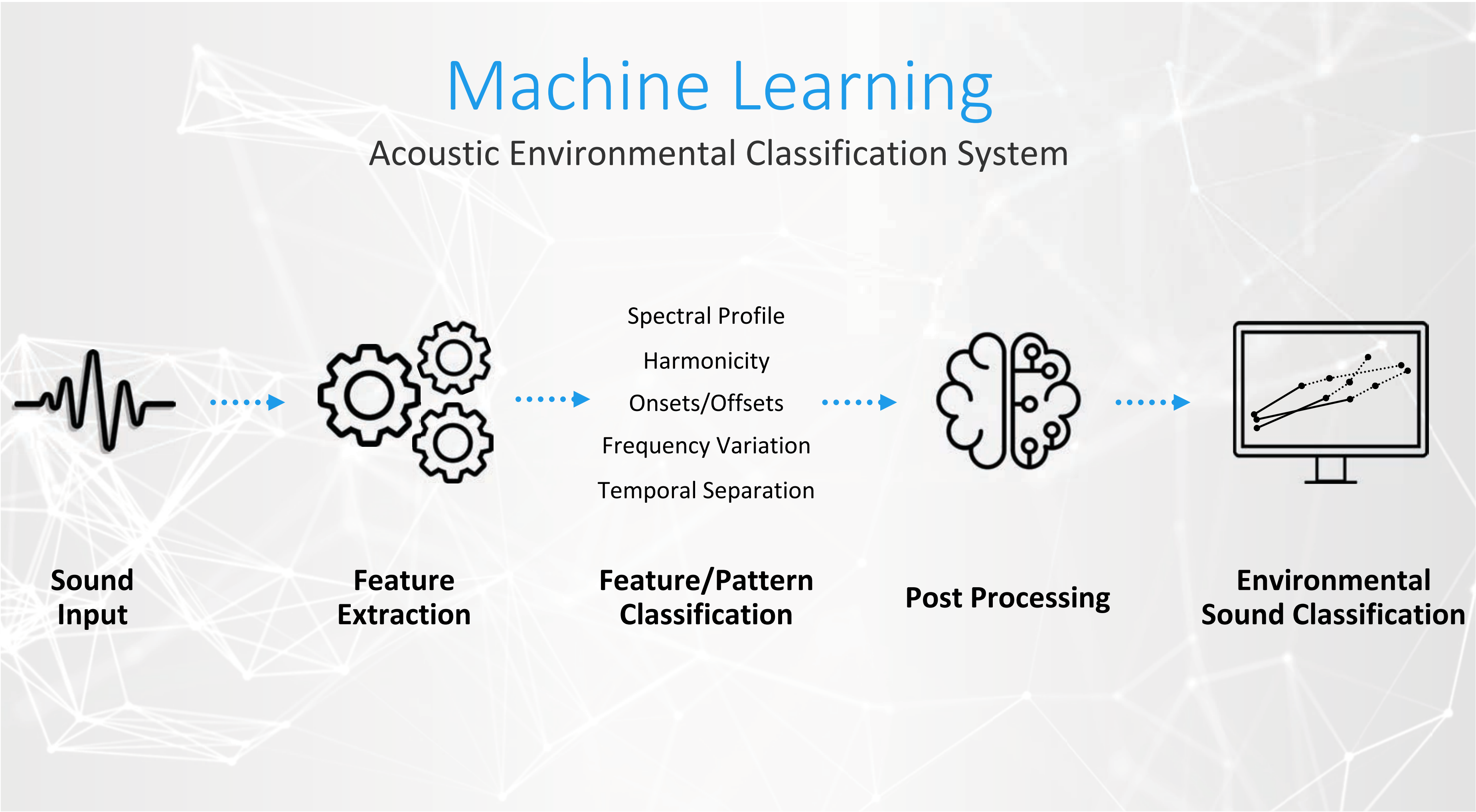
1:1 conversation	83%
Workplace	82%
Small group conversation	78%
Outdoors	77%
Shopping	77%
Car	76%
Large group conversation	72%
Conversation in noise	72%
Large lecture hall	72%
Classroom	70%

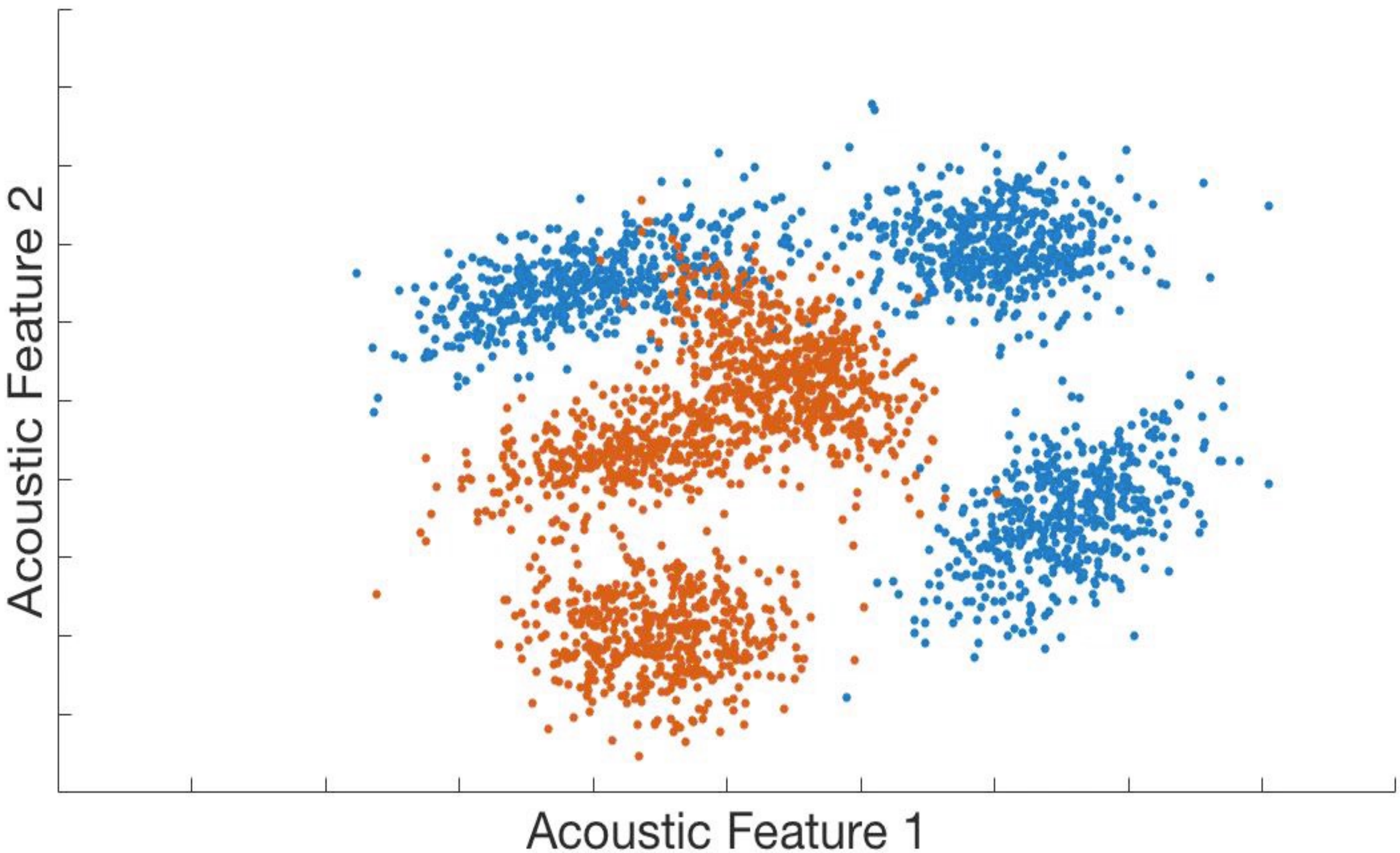
Picou EM. Hearing Aid Benefit and Satisfaction Results from the MarkeTrak 2022 Survey: Importance of Features and Hearing Care Professionals. Semin Hear. 2022 Dec 1;43(4):301-316.

Most modern hearing aids use an acoustic environmental classification feature to identify and classify the current listening environment, and automatically apply environment-specific changes to gain, microphone, compression, and noise reduction settings

But how does the classifier know what the listener ***WANTS*** to hear?


AI-based Sound
Classification

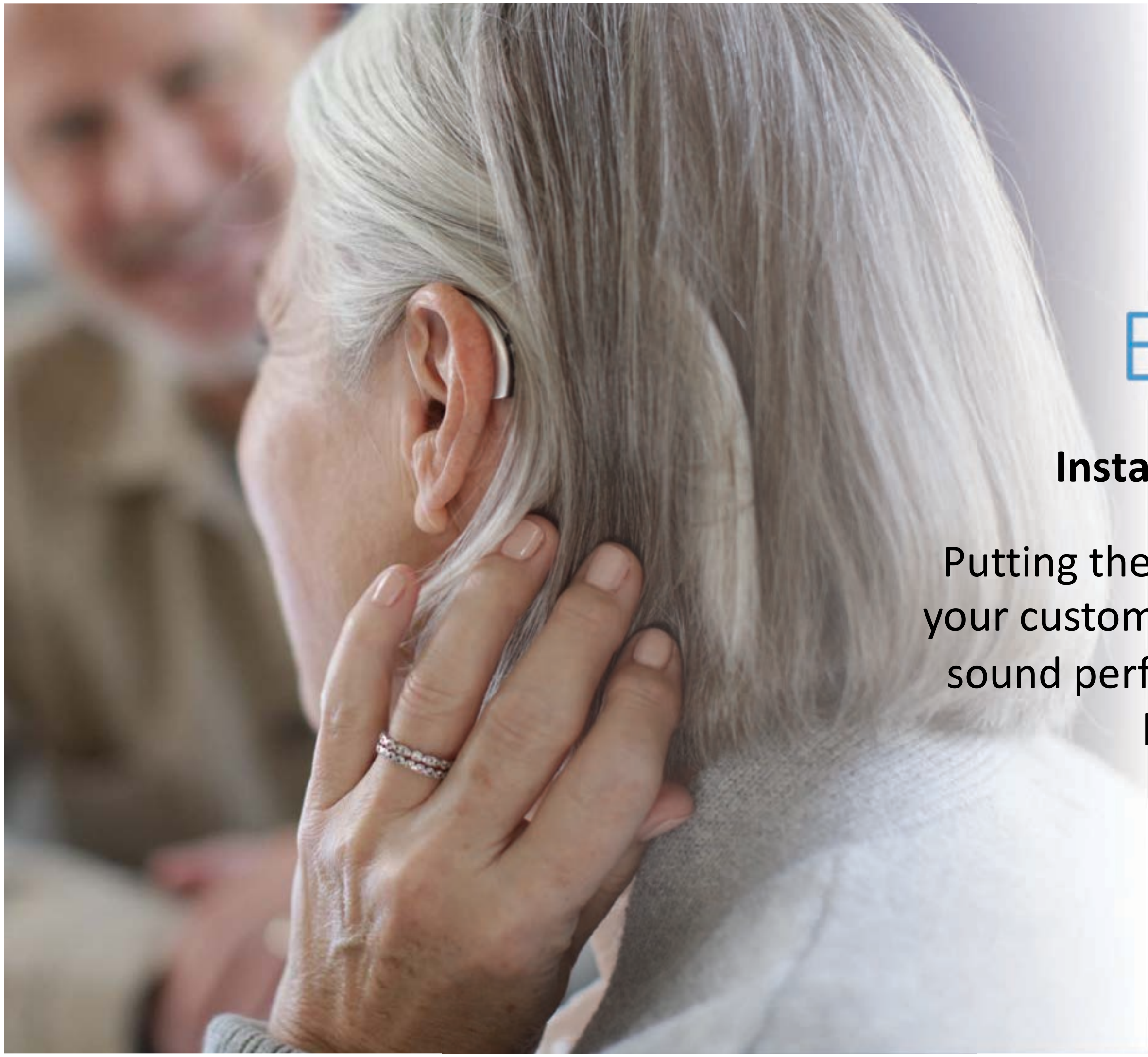

Machine Learning
Acoustic Environmental Classification System
Spectral Profile
Harmonicity
Onsets/Offsets
Frequency Variation
Temporal Separation
Sound Input
Feature Extraction
Feature/Pattern Classification
Post Processing
Environmental Sound Classification



Acoustic Feature 2
Acoustic Feature 1


ONE WAY
St. Peter

Sound is personal



Edge Mode

Instant Optimized Adjustments

Putting the power of artificial intelligence at your customer's fingertips for next-generation sound performance in the most challenging listening environments

Edge Mode Workflow

User Requests Assistance

User requests assistance by pushing button on the hearing aid or in the smart phone app

Env Detected & Parameters Retrieved

Environment is detected by analyzing hearing aid parameters and appropriate stored offsets are retrieved for listening

User Listens to New Parameters

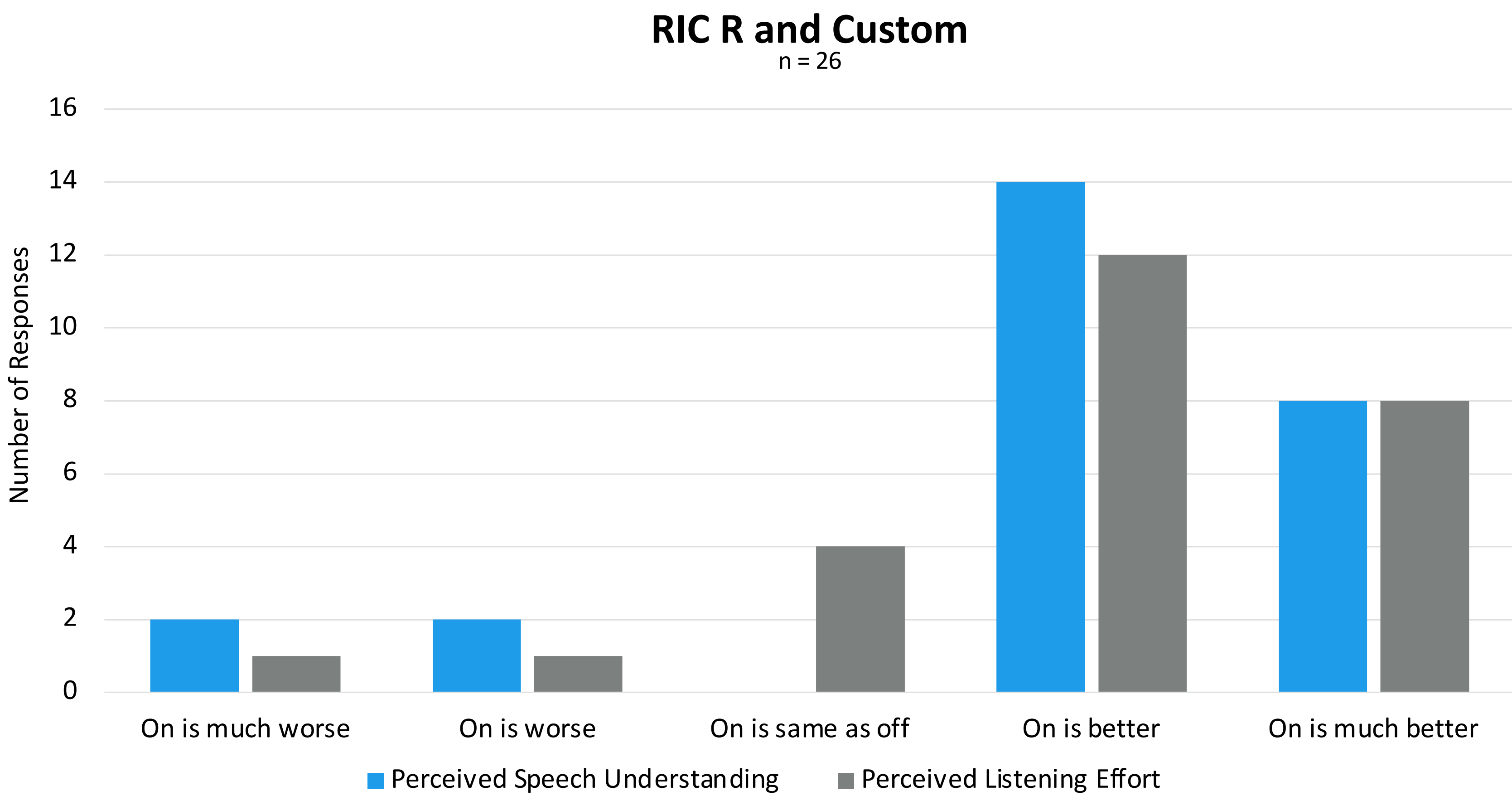
User listens to the new setting in the problematic environment

User Accepts Or Rejects Parameters

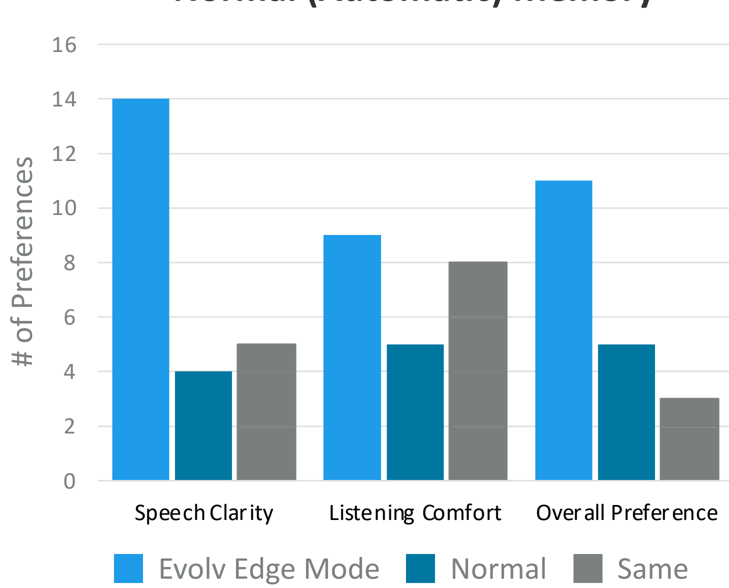
User can continue to listen to the new settings (considered acceptance) or user can switch back to their prior setting


Next-Gen
Edge Mode
Instant Optimized Adjustments
Putting the power of artificial intelligence at the patient’s fingertips for the most challenging listening environments

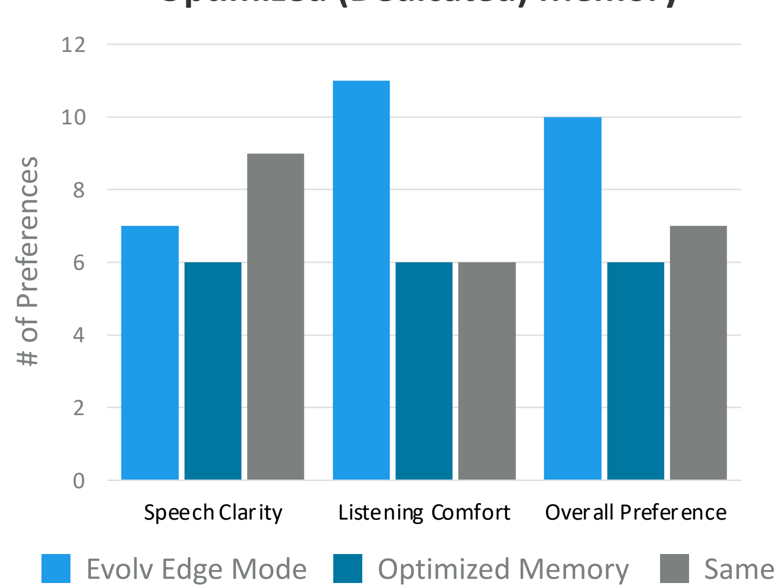
Edge Mode vs. Normal (Automatic) Memory



Edge Mode preferred for clarity, comfort, and overall preference



Edge Mode same or better than the optimized dedicated HA memory



+ = Car Memory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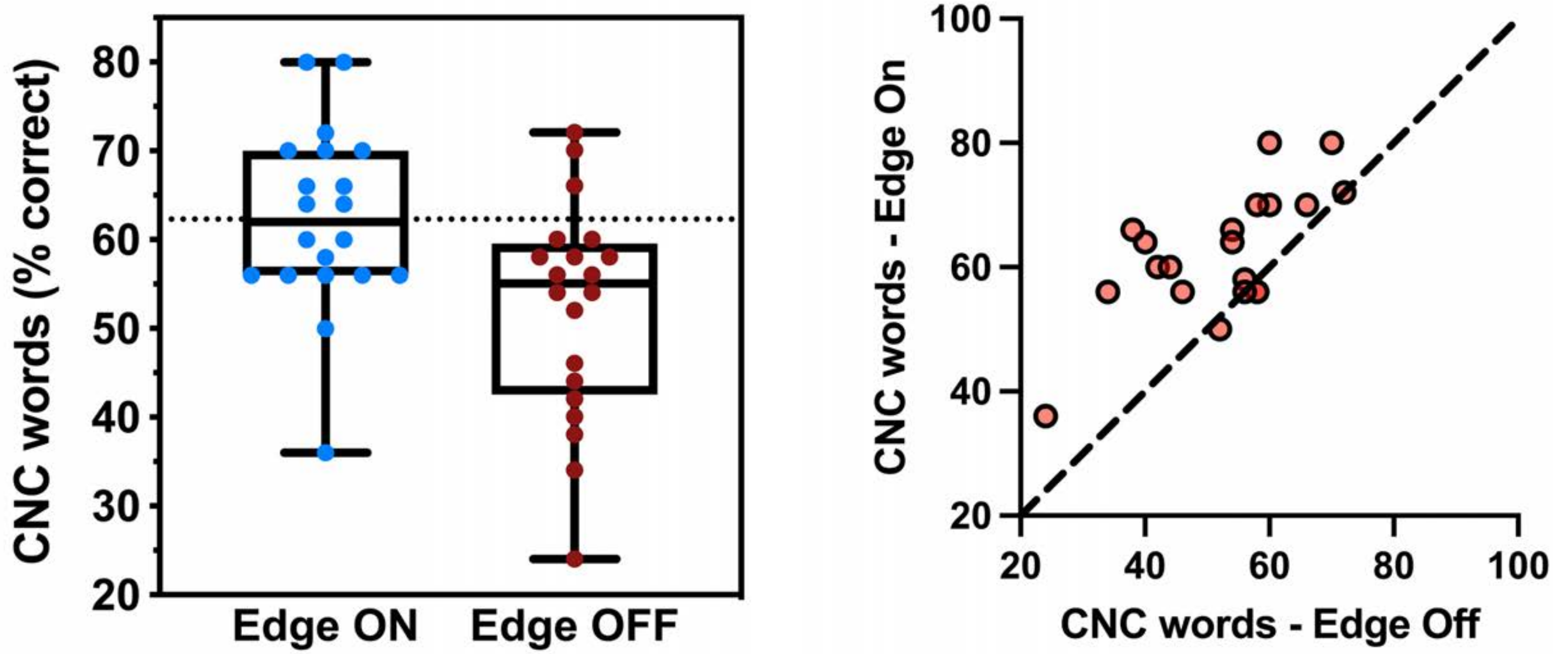
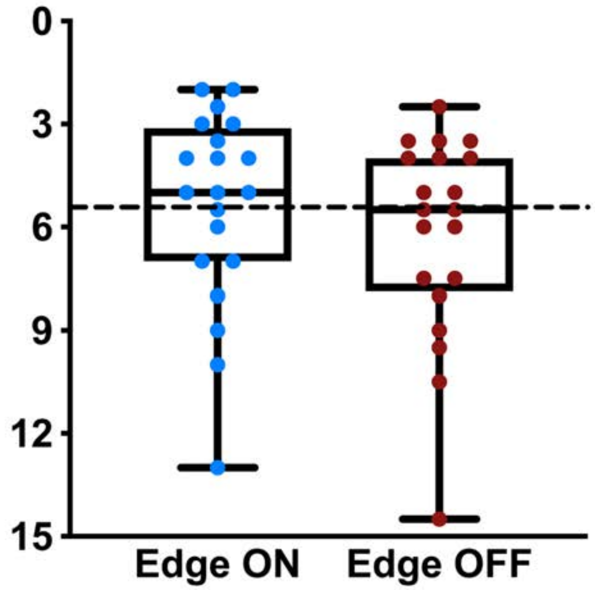
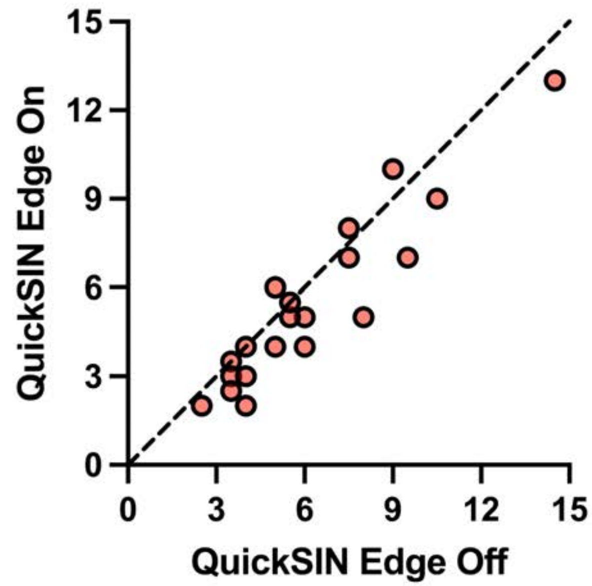


CNC word scores in multi-talker babble at +5 SNR
are **generally higher when Edge AI is active**

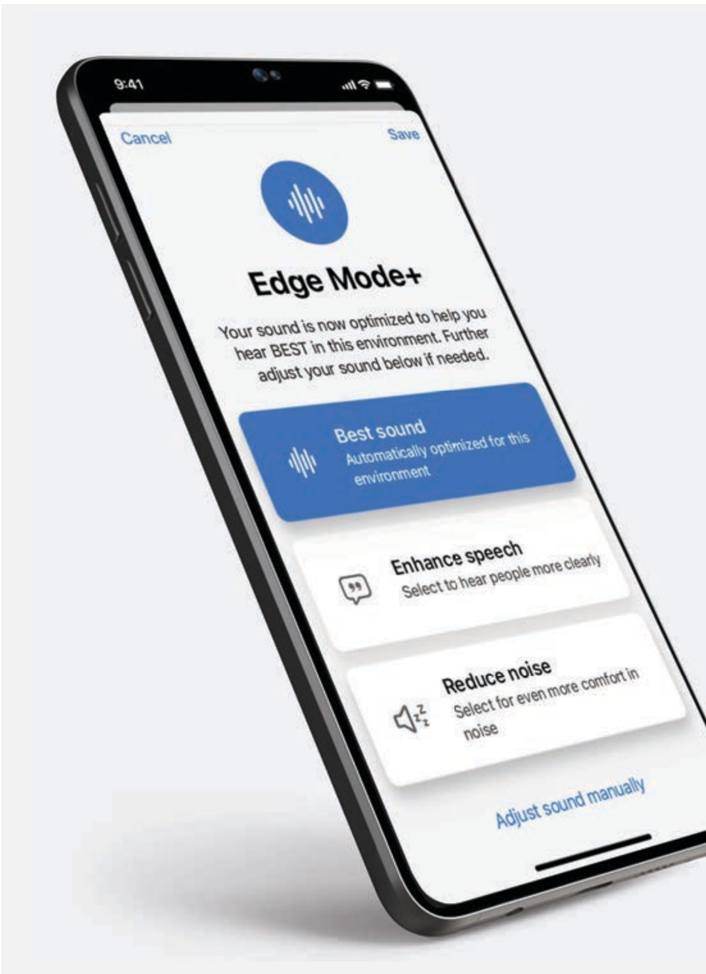
QuickSIN SNR loss is lower by

~ 1 dB on average when Edge AI is active






Dave Fabry

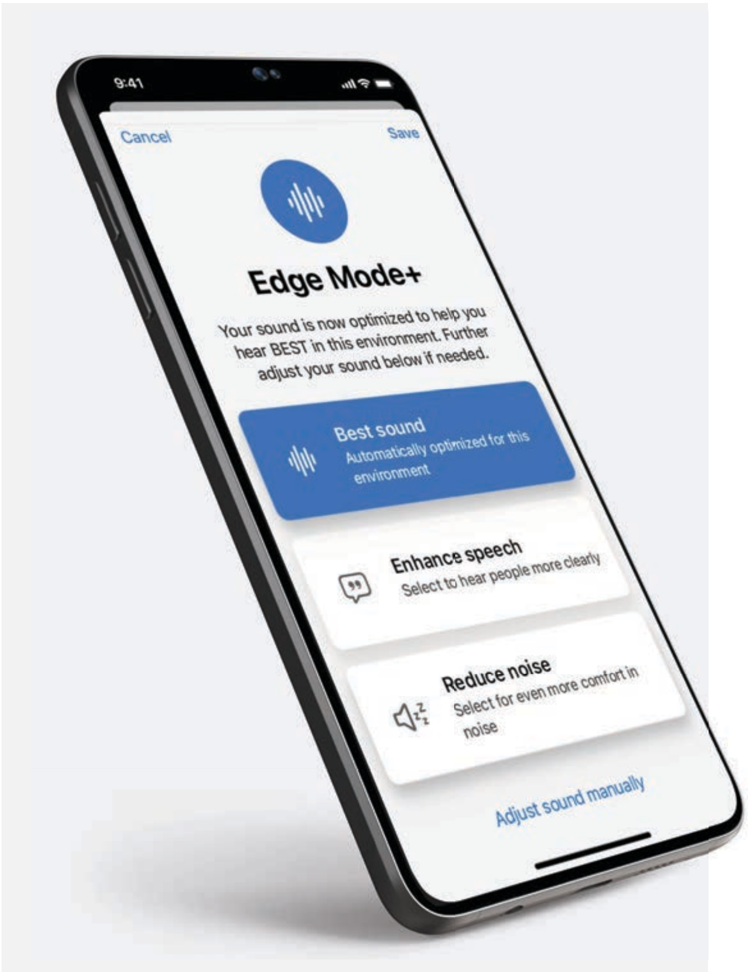


Edge Mode+

With the goal of helping patients in difficult listening situations, an <u>on-demand</u> processing feature was designed for Genesis AI

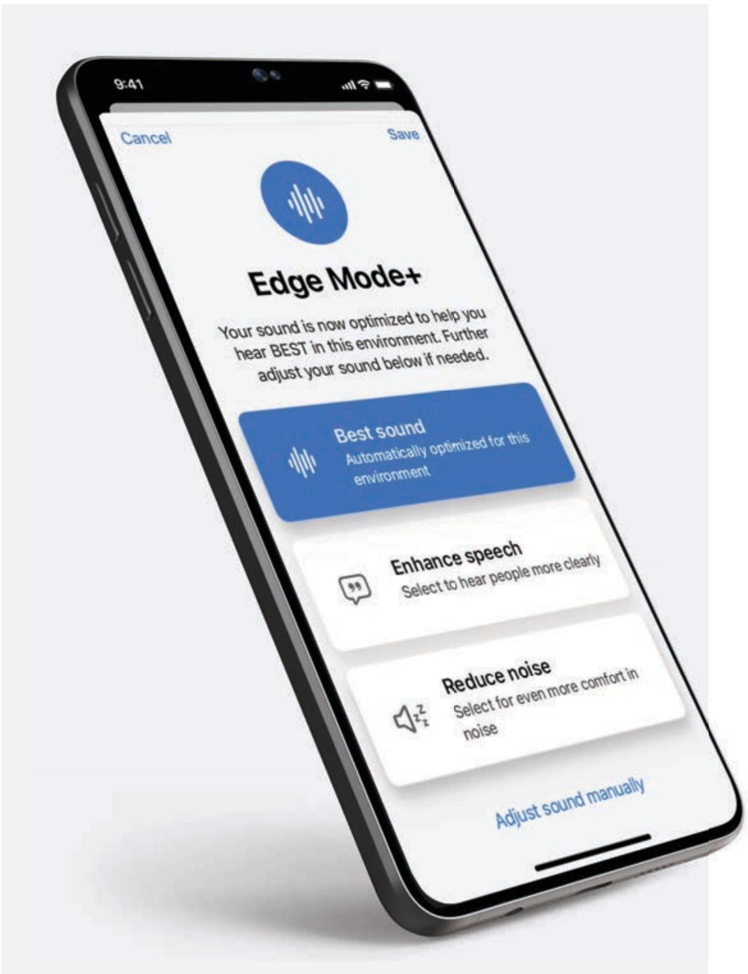
Edge Mode+ allows the patient to identify their listening intent (Enhance Speech or Reduce Noise) and optimize hearing aid features for preferred patient outcomes

EXCLUSIVE
24 & 20
TECHNOLOGY



Edge Mode+

When activated by the user,
the hearing aid classifies the listening environment and applies specialized changes to the hearing aid features **beyond** that available in default hearing aid settings and based on the **listener's intent**



Edge Mode+

These classification and adaptation schemes were derived via machine learning and the use of a **Deep Neural Network (DNN)** accelerator engine, in which models were trained on a large number of real-life sound recordings and refined via input from both clinicians and listeners

Edge Mode+

Study 1

Benefits of Edge Mode+ on Speech Understanding in Noise

Study 2

Benefits of Edge Mode+ on Listening Effort

Study 3

Individual differences for Edge Mode+ benefit

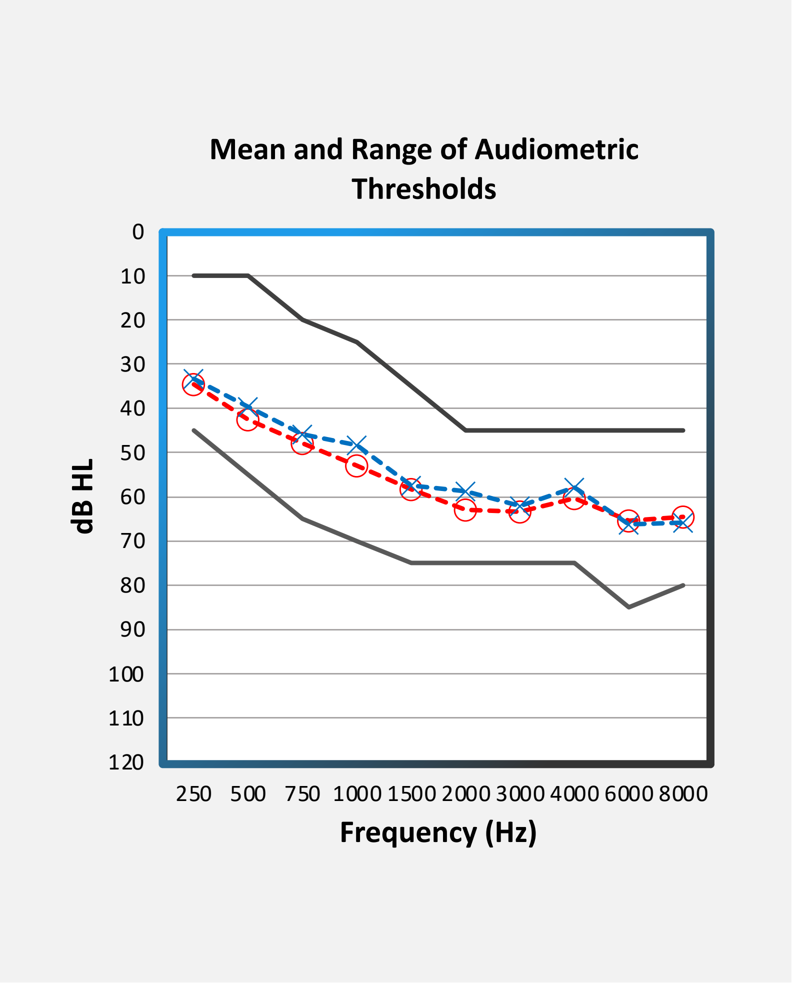
Speech Understanding in Noise

Participants

- 12 Experienced hearing aid users
- 5 females, 7 males
- 42-84 years (mean 71.1 years)

Hearing Aid Fitting

- Starkey Genesis AI 24 RIC Devices
- Audiometrically appropriate coupling
- e-STAT 2.0 Fitting Formula



Speech Understanding in Noise

Conditions

Default Hearing Aid Processing

Edge Mode+ Enhance Speech

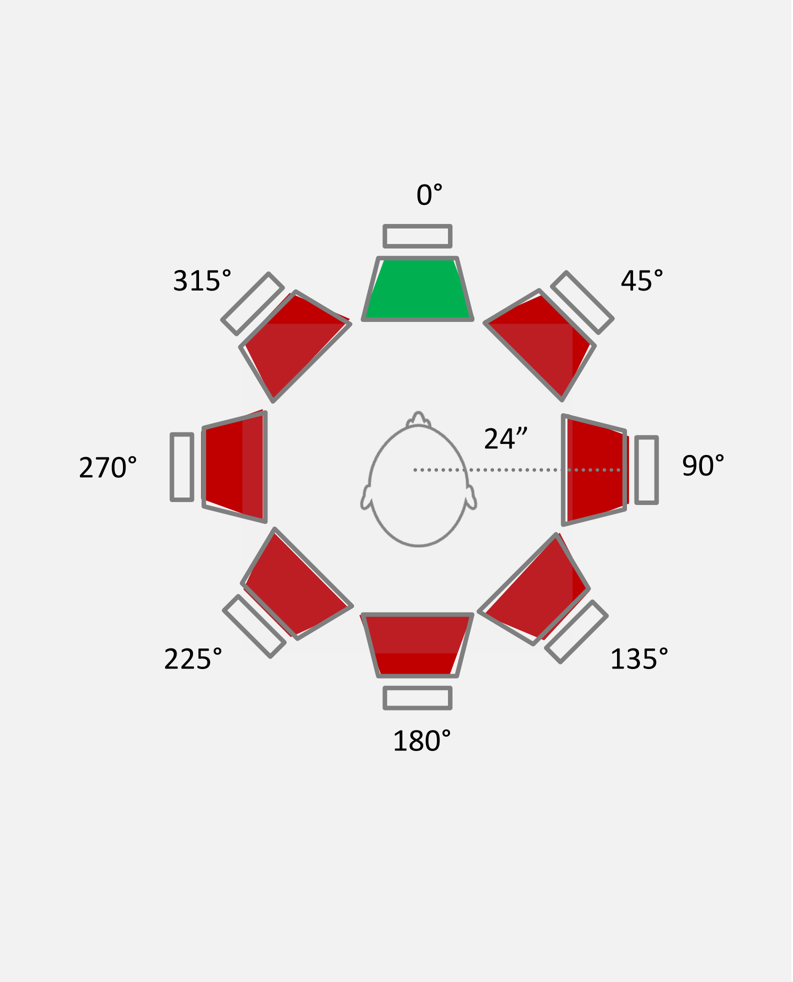
Speech

IEEE Sentences

Presented at individualized level to achieve ~70% speech understanding with default hearing aid processing

Noise

Restaurant Noise at 63 dB A

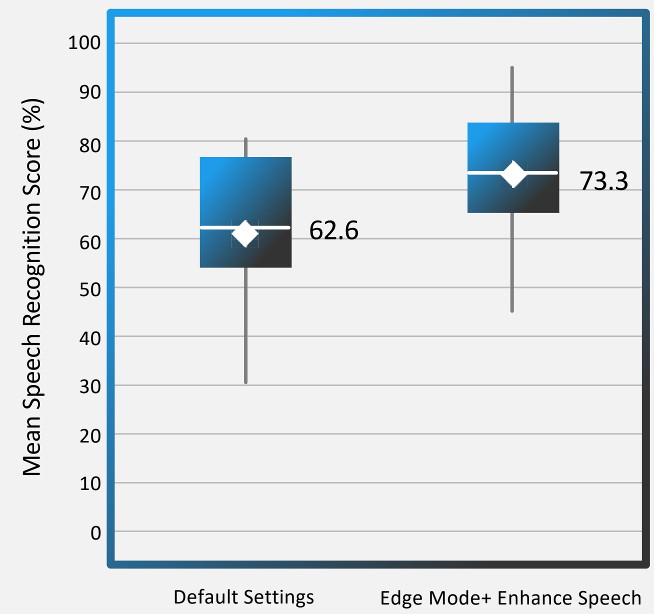


Speech Understanding in Noise

Speech Recognition performance in percent correct was converted to rationalized arcsine units (RAU) for analysis

Edge Mode+ resulted in **significantly better speech recognition in noise** than default hearing aid settings

($t(11) = 2.55$, $p=0.027$)



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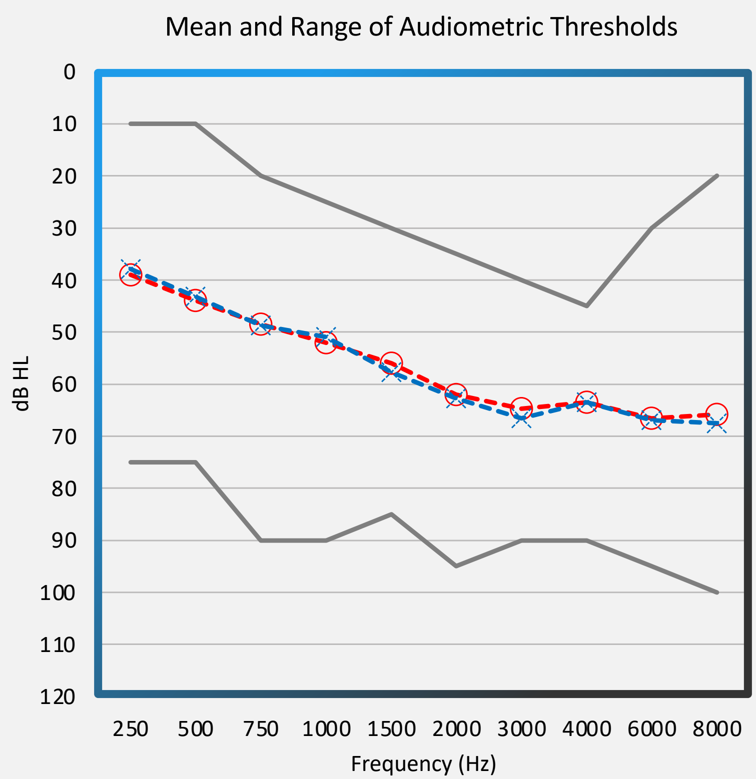


Listening Effort

Participants

20 Experienced hearing aid users

5 females, 15 males

42-84 years (mean 71.2 years)

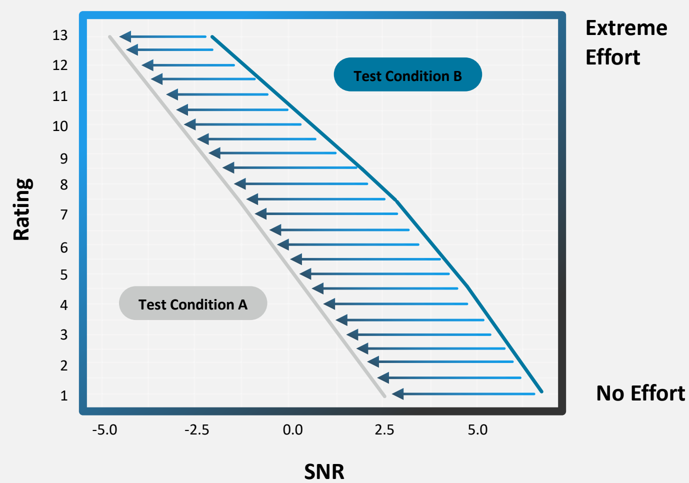
Hearing Aid Fitting

Starkey Genesis AI 24 RIC Devices

Audiometrically appropriate coupling

e-STAT 2.0 Fitting Formula

Example ACALES data



$$\boldsymbol{mean\ SNR\ benefit} = \frac{\sum_{i=1}^{n}(SNR_{Test\ Ai} - SNR_{Test\ Bi})}{n}$$

Krueger M, Schulte M, Brand T, Holube I. Development of an adaptive scaling method for subjective listening effort. J Acoust Soc Am. 2017 Jun;141(6):4680.

Listening Effort

Conditions

Default Hearing Aid Processing

Edge Mode+ Enhance Speech

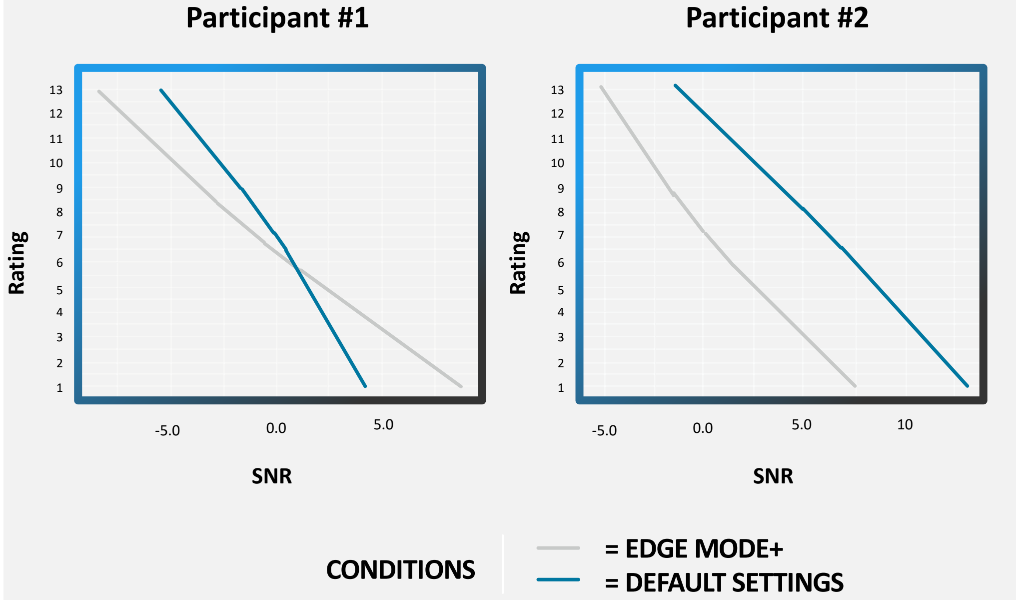
Task

Adaptive Categorical Listening Effort Scale (ACALES)

Speech: English Matrix Test

Noise: Modulated Noise (ICRA250)

Rate Listening Effort across a range of SNR values (fixed noise level)



Participant	Left Threshold (dB HL)				Right Threshold (dB HL)				Word Recognition (%)	
	0.5k	*1k*	*2k*	*4k*	*0.5k*	*1k*	*2k*	*4k*	*Left*	*Right*
#1	50	50	65	65	50	50	60	65	82	78
#2	55	60	70	75	55	70	60	55	84	78

Listening Effort

Mean SNR benefit increased by 1.13 dB*, indicating that **Edge Mode+ can improve (reduce) listening effort**
**(t(19) = 2.08, p=0.05)*

Individual mean SNR benefit values varied greatly even for those with similar hearing losses

Thus, as an on-demand feature, Edge Mode+ can provide significant benefit for those patients that need additional assistance in noisy or difficult situations

Edge Mode+

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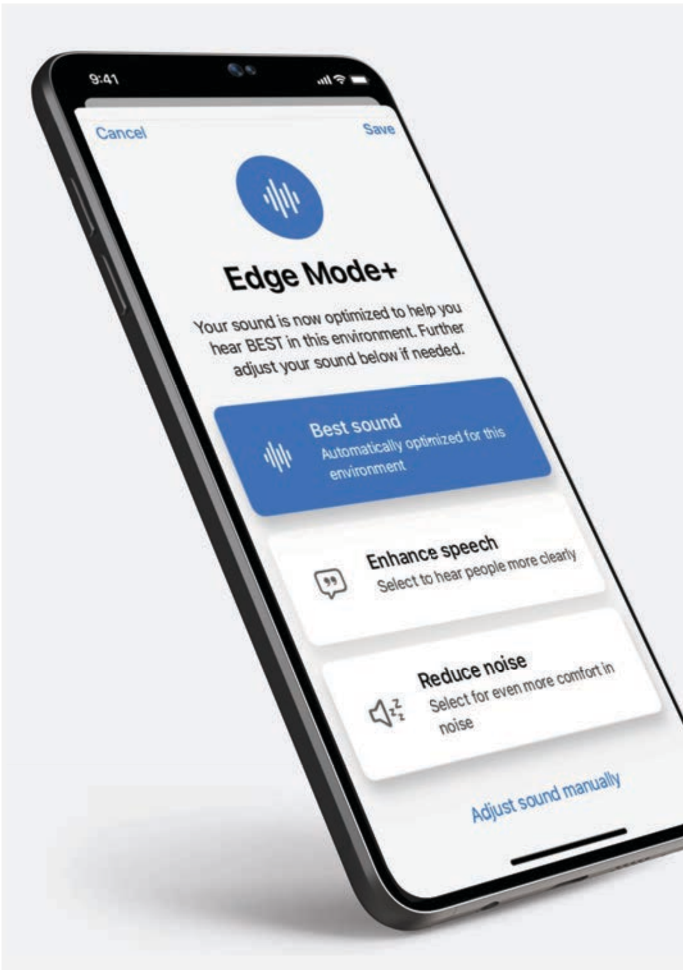
Individual differences for Edge Mode+ benefit



Automatic Edge Mode+

Continues to scan, adapt and optimize as the acoustic environment changes, ensuring the most appropriate settings are always applied in a dynamic world

of patients report
benefits from Edge Mode+
in everyday listening environments

Top Drivers

of Hearing Aid Performance and Sound

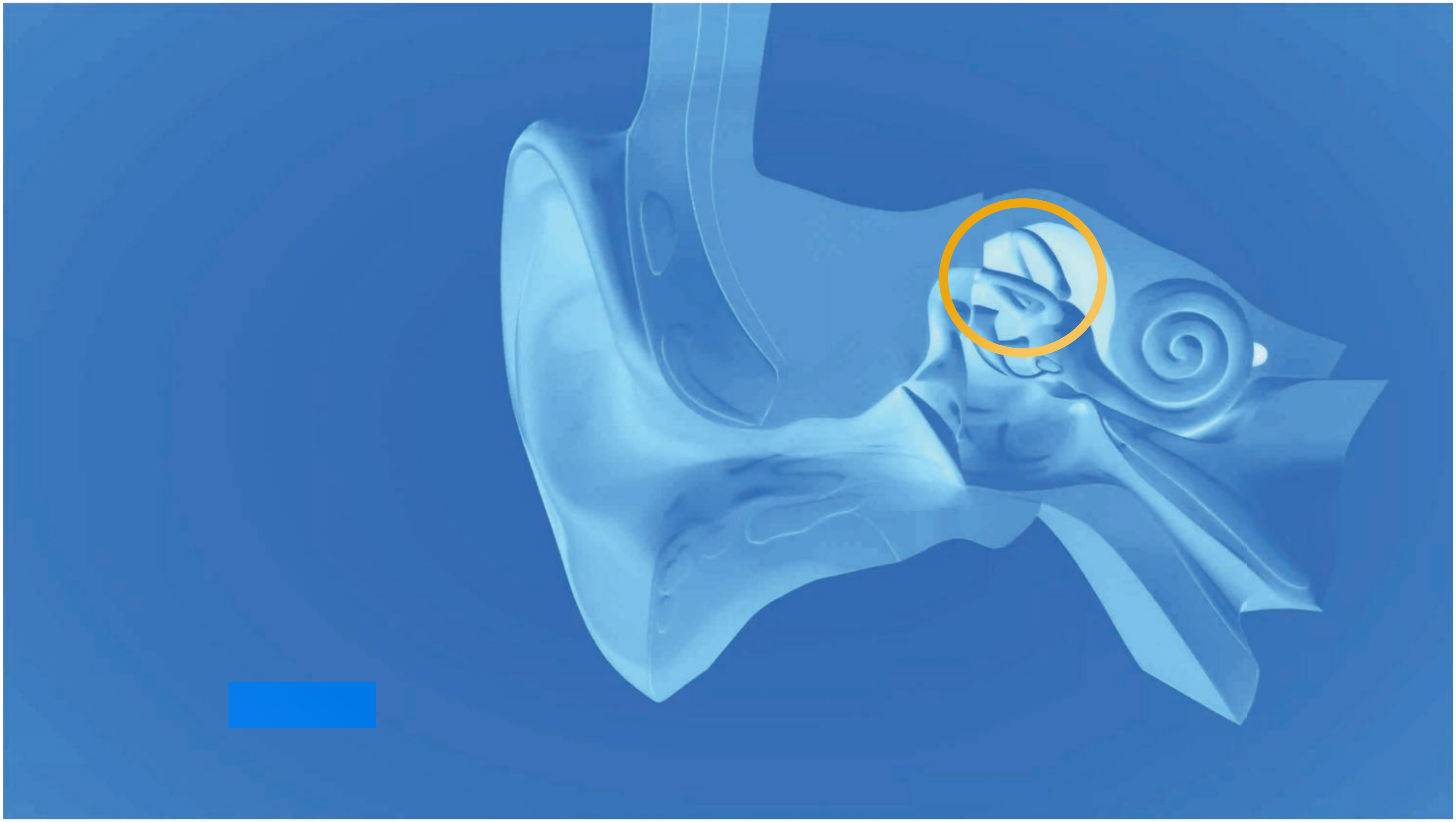
Natural Sounding
Rich and Clear

Comfort for loud sounds

Minimize background noise

Ability to tell direction

MarkeTrak 10 / Hearing Industries Association, 2019

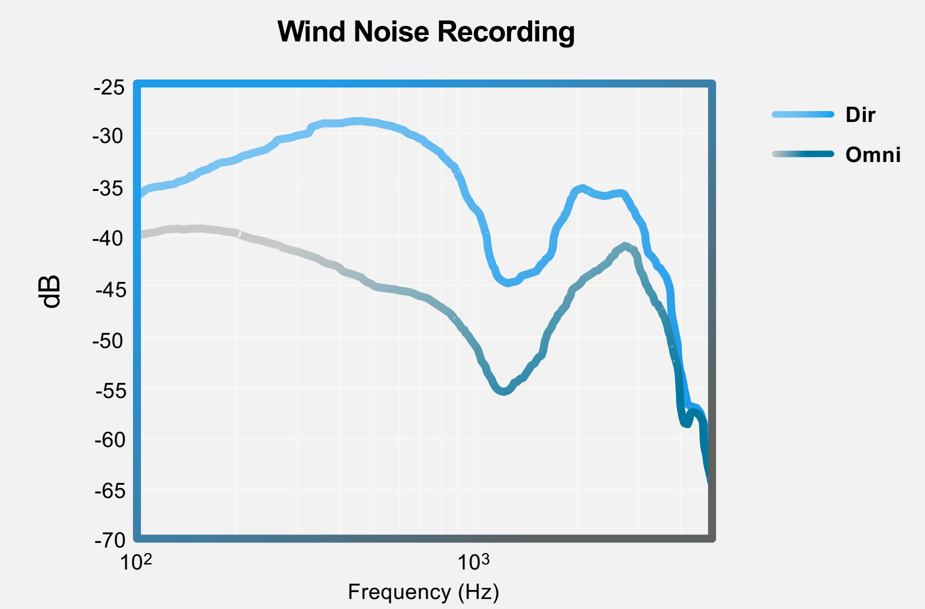


Motion-Based Optimization

Motion detection adaptations improve sound quality and increase spatial awareness

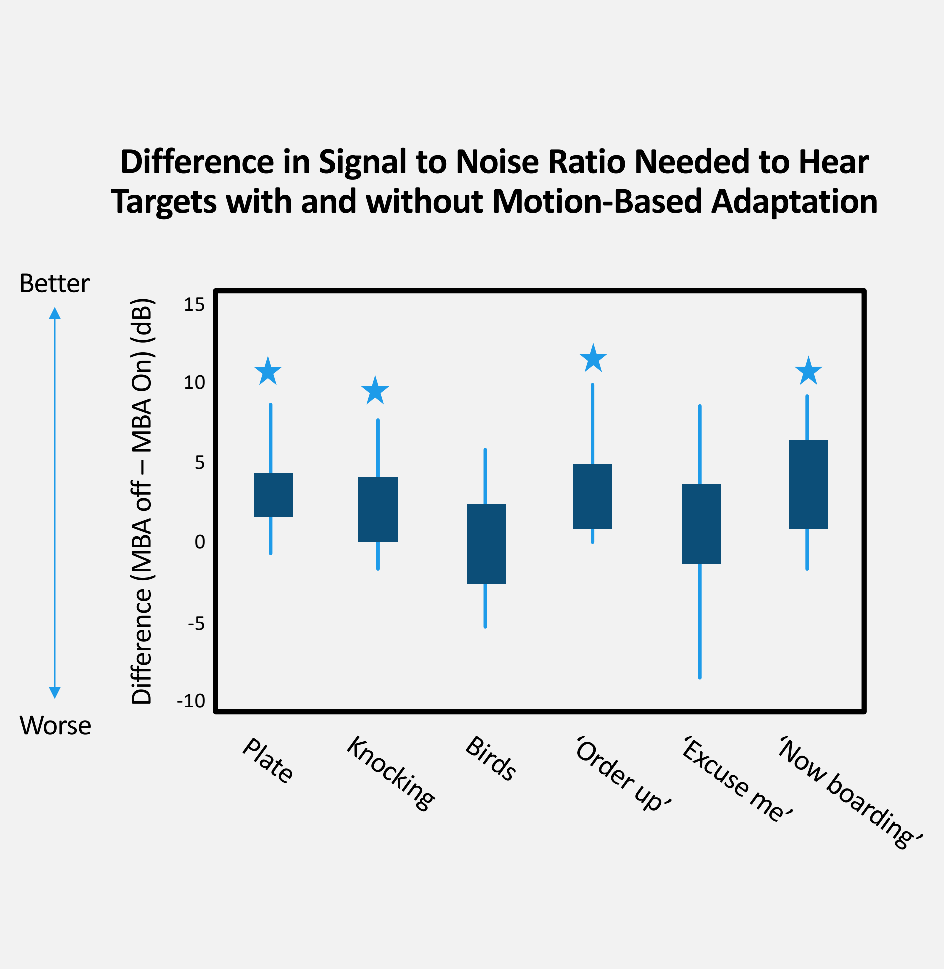
Improved Wind Noise Reduction

Less wind noise in omni-directional when the user is in motion



Improved Spatial Awareness

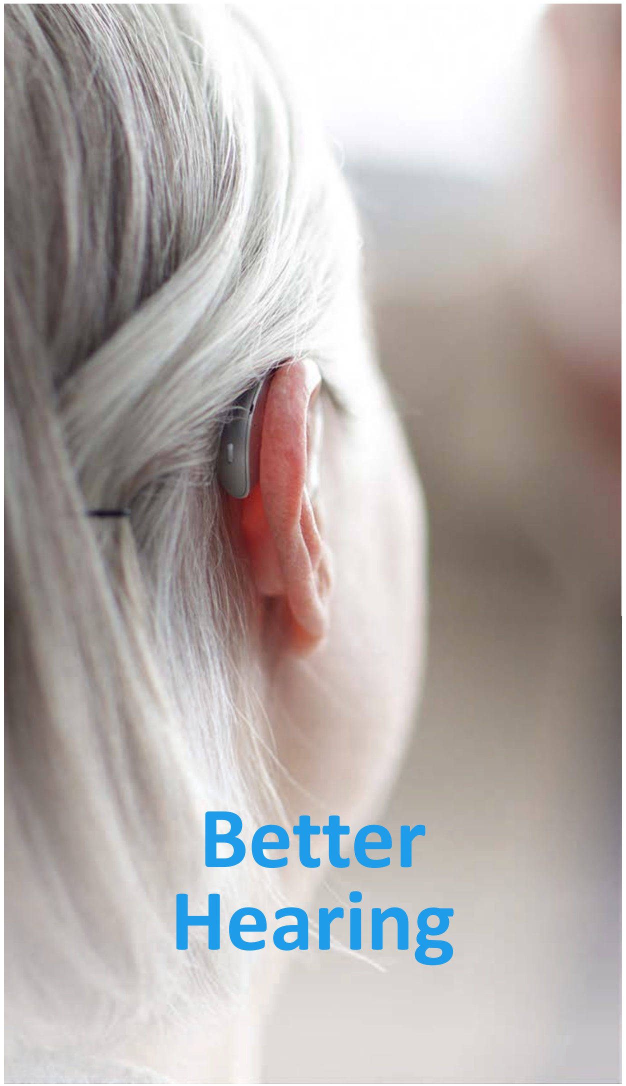
Statistically significant improvement in the SNR needed to achieve “soft but audible” audibility for target signals



Improved Feedback Management

10%

greater gain margins
to prevent feedback during activity


Better
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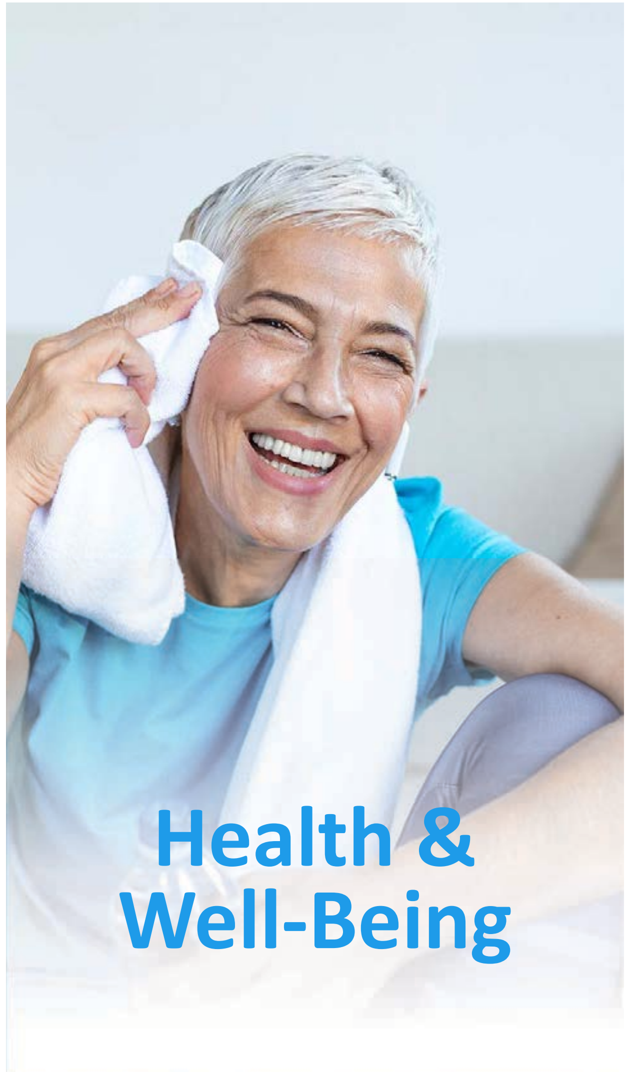
Health &
Well-Being


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Assistant


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Fall Prevention

Fall Detection

Artificial Intelligence in Hearing Aids

Can hearing aids assess fall risk?

Falls are the leading cause of injury-related deaths in older adults

Falls result in over $31 billion in medical costs per year

Can AI driven changes in signal processing improve the signal to noise ratio?

How large are the improvements?

In which circumstances are these improvements observed?

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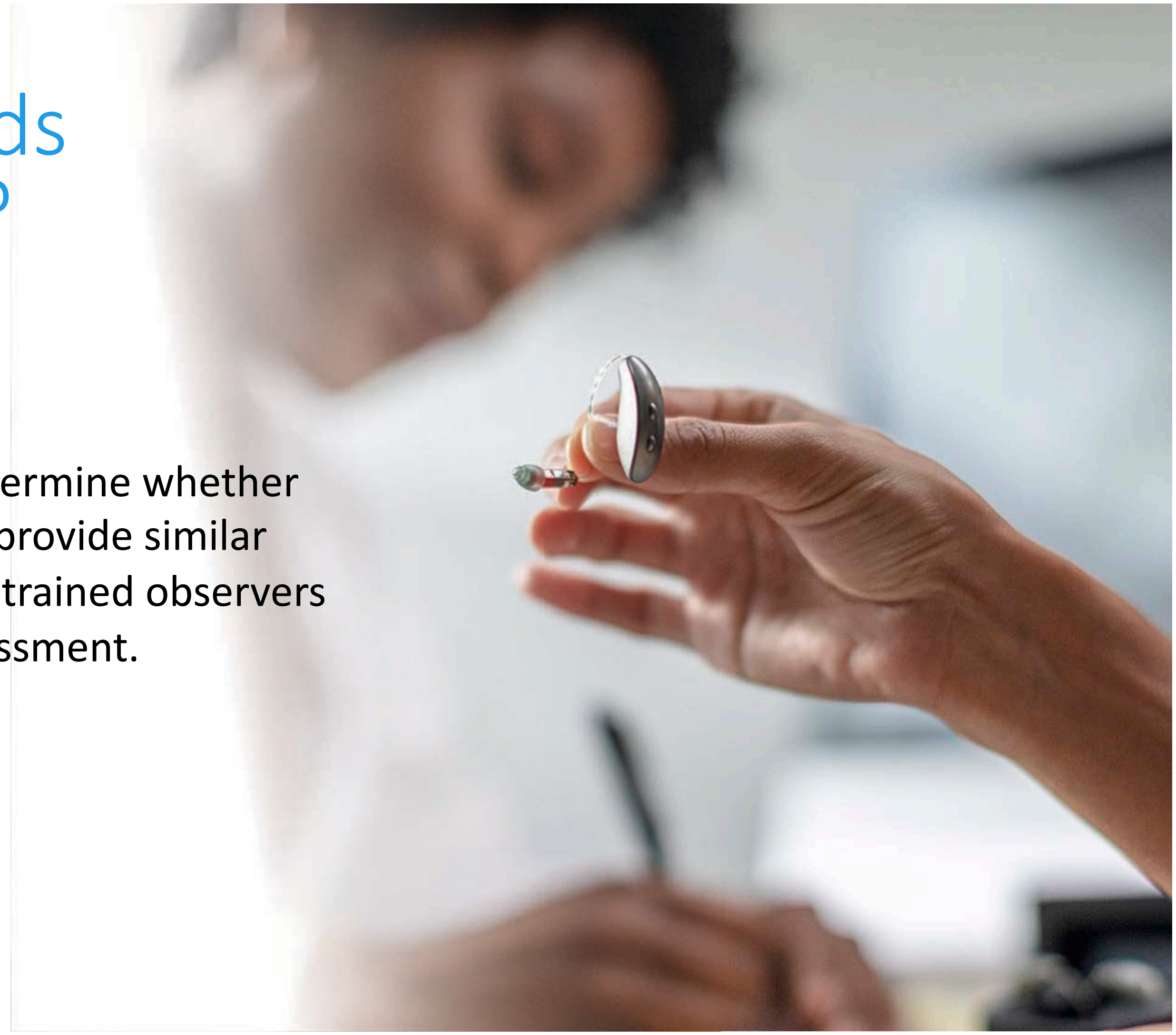
Can hearing aids assess fall risk?

Our goal is to determine whether hearing aids can provide similar ratings to that of trained observers on a fall risk assessment.



Hearing Aids are embedded with additional sensors

Inertial Sensor Data

Start
Phone App
Stop

Accelerometer – detect velocity changes
Gyroscope – detect rotation

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Participant Inclusion Criteria

Centers for Disease Control and Prevention (CDC) suggests these three questions, that **identify 95% of patients** who are at risk for falling.

Eckstrom et al., 2017

At least ONE of the following should apply:

1. **Unsteady while walking**
2. **Worry about falling**
3. **Have fallen in the last year**

Methods

1. **4-Stage Balance Test**
   ↓
   Balance
2. **30-Second Chair Stand Test**
   ↓
   Strength
3. **Timed Up & Go Test**
   ↓
   Functional Gait

Participants (n=250)
Aged 55-100 years (mean = 78yr)
Sex: 62.4% females, 37.6% males

↓

CDC's Stopping Elderly Accidents, Deaths, and Injuries (STEADI)

↓

3 Observers

Left & Right Hearing Aids

The STEADI algorithm accurately measures fall risk among older adults

Limitations

Fair sensitivity and specificity in discriminating low vs. high fall risk

Not specific in predicting mortality risk or other risk factors

Advantages

Simplicity

Coordination between clinical and community-based practice

Suitable for widespread implementation

1

4-Stage Balance Test Procedure

Side Stand with your feet side-by-side.		Try to balance for 10 seconds
Instep Place the instep of one foot so it is touching the big toe of the other foot.		Try to balance for 10 seconds
Tandem Place one foot in front of the other, heel touching toe.		Try to balance for 10 seconds
One Foot stand on one foot – whichever foot you prefer.		Try to balance for 10 seconds

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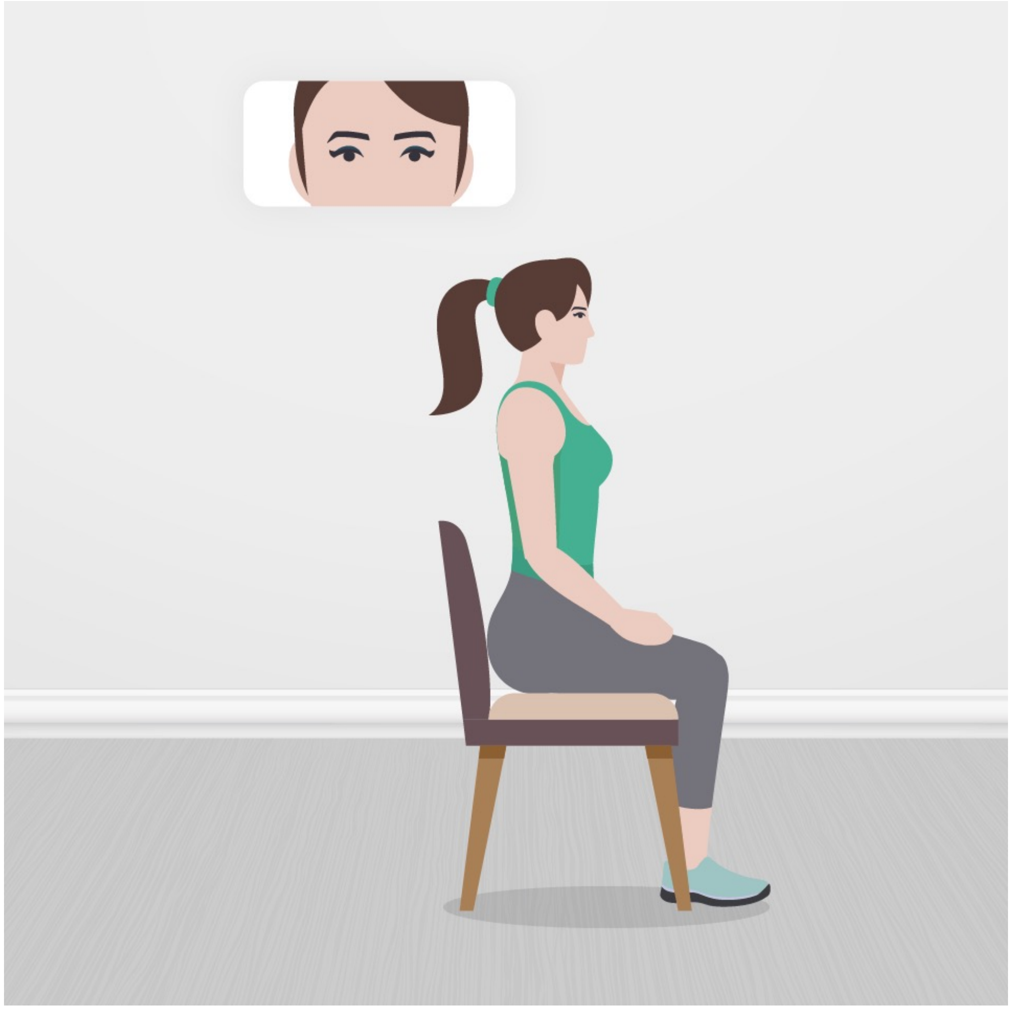
2

30-Second Chair Stand



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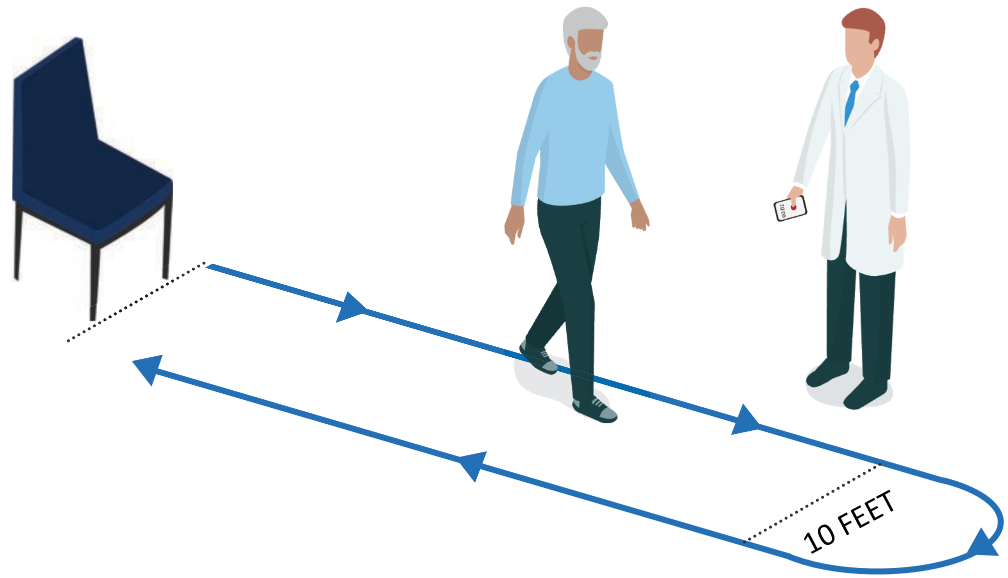
3

Timed Up & Go (TUG)



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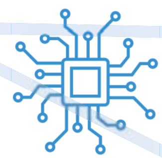
Hearing Aids

Accelerometer – detect velocity changes
Gyroscope – detect rotation

Start
Phone App
Stop

Algorithm Decision



4-Stage Balance Test
PASS/FAIL

30-Second Chair Stand Test
STAND COUNT

Timed Up & Go Test
TIME

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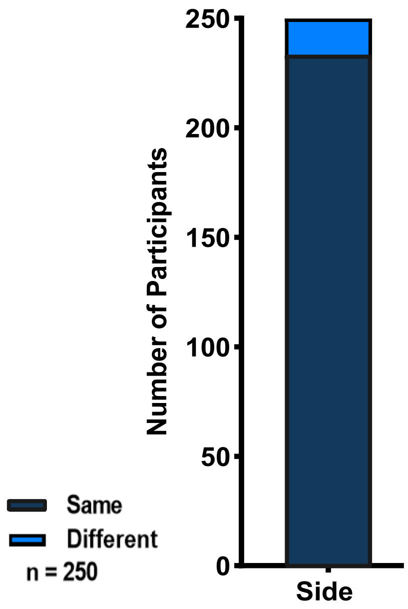
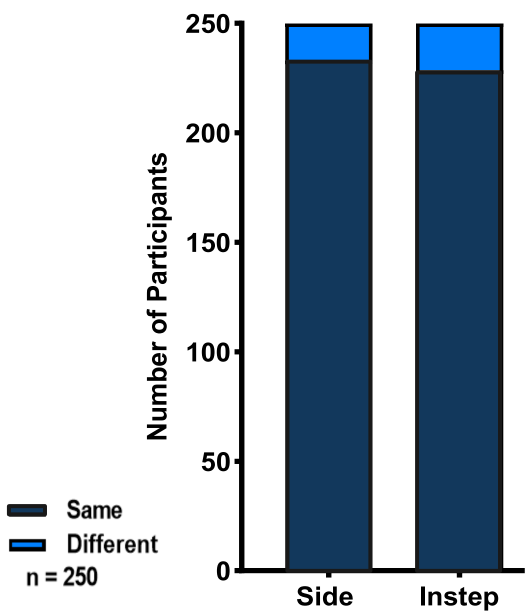
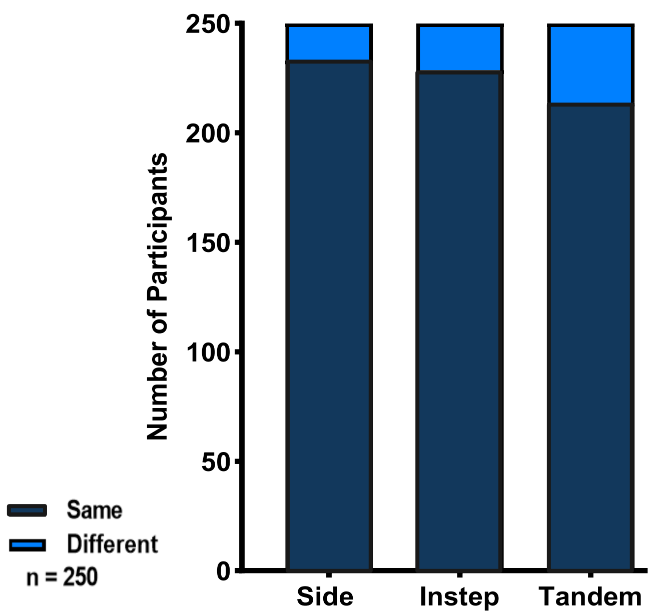
Observers and hearing aids had 93% scoring agreement for the side position



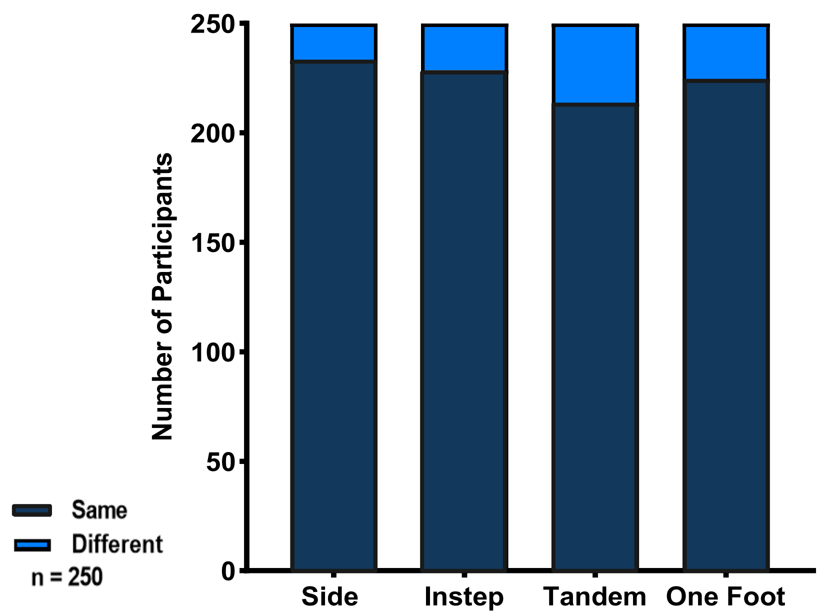
Observers and hearing aids had 91% scoring agreement for the instep position



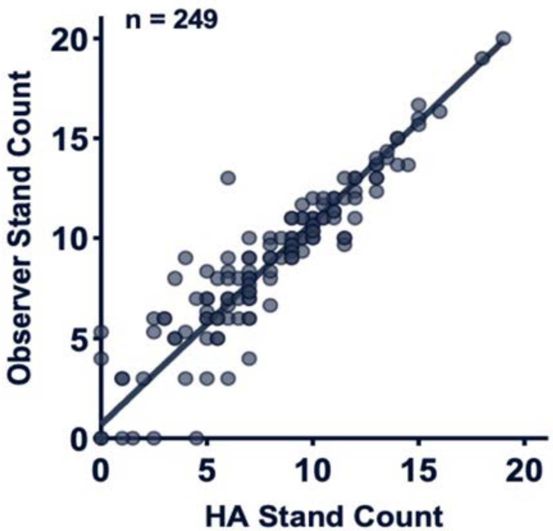
Observers and hearing aids had 86% scoring agreement for the tandem position



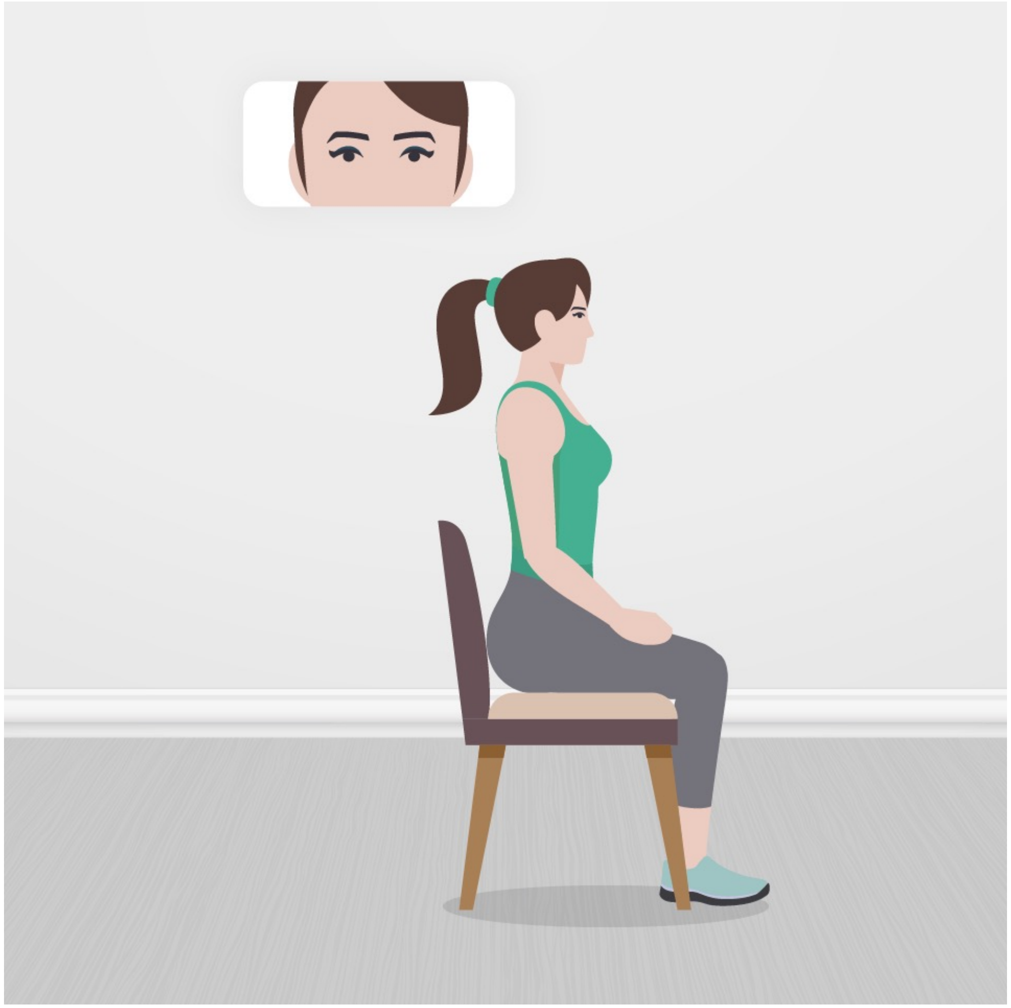
Observers and hearing aids had 90% scoring agreement for the one-foot position



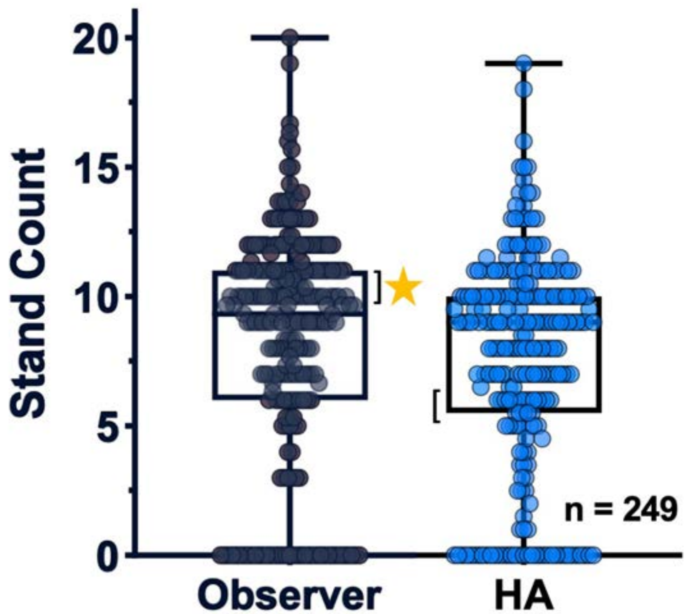
Strong relationship between HA and observer on 30 Second Chair Stand



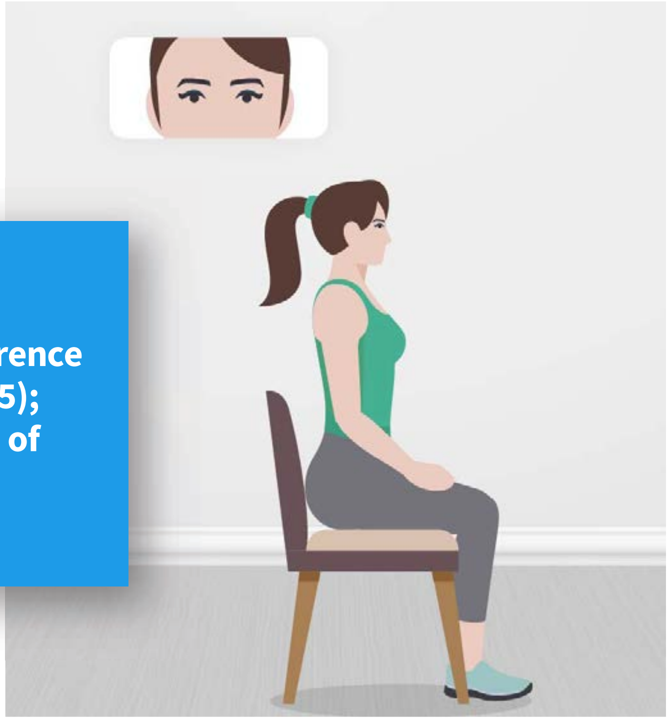
(R^2 = 0.93; P<0.001)



Observers report nearly one more stand count than HA

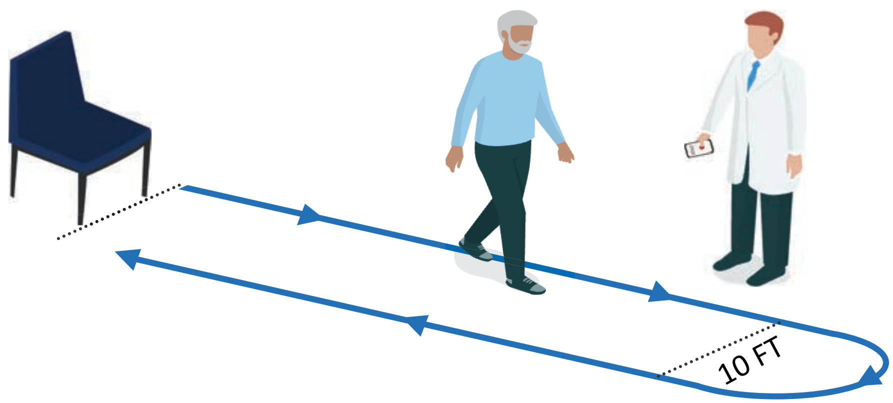


★ **Statistically significant difference (t = 10.13, p<0.05); Mean difference of 0.8 stand count**

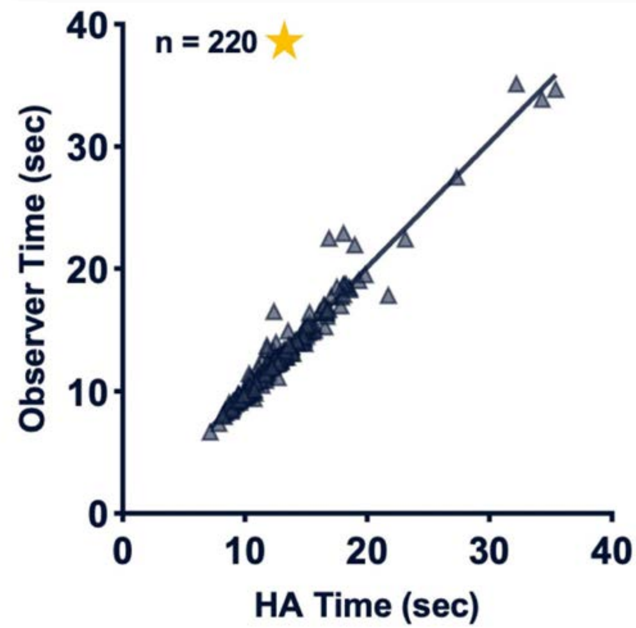


21% of participants scored by clinician would be at risk of pass/fail misclassification from a 1 stand count mistake

Strong relationship between HA and observer on Timed Up & Go

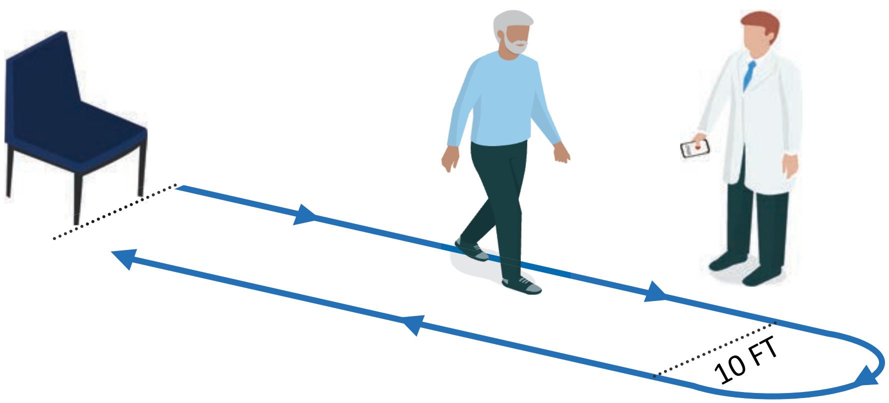


★ Hearing aids could not calculate time for 30 participants (n = 220)



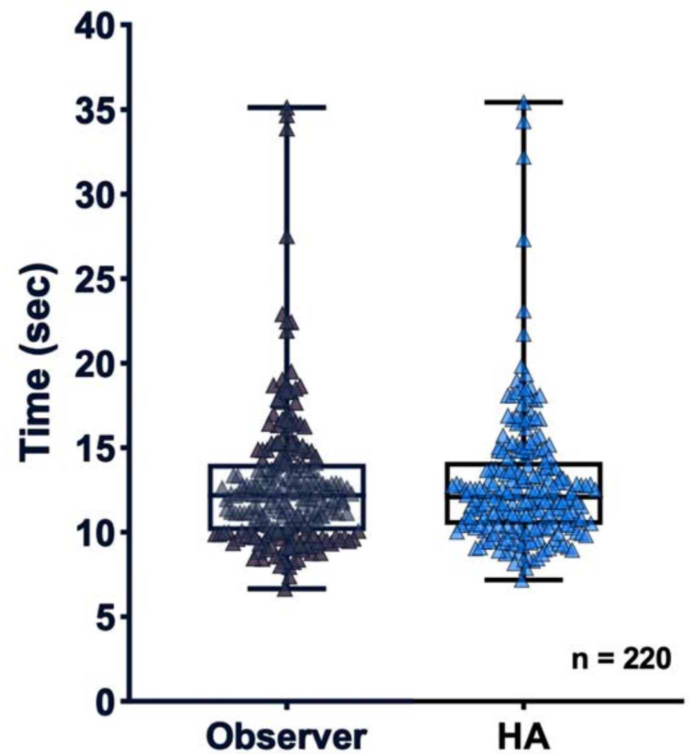
(R2 = 0.96; P<0.001)

Mean duration was similar between HA and observer on Timed Up & Go



No statistically significant difference

($t = 0.94$, $p>0.05$)



Summary

Remote assessment limitations

Observers have the luxury of visual context

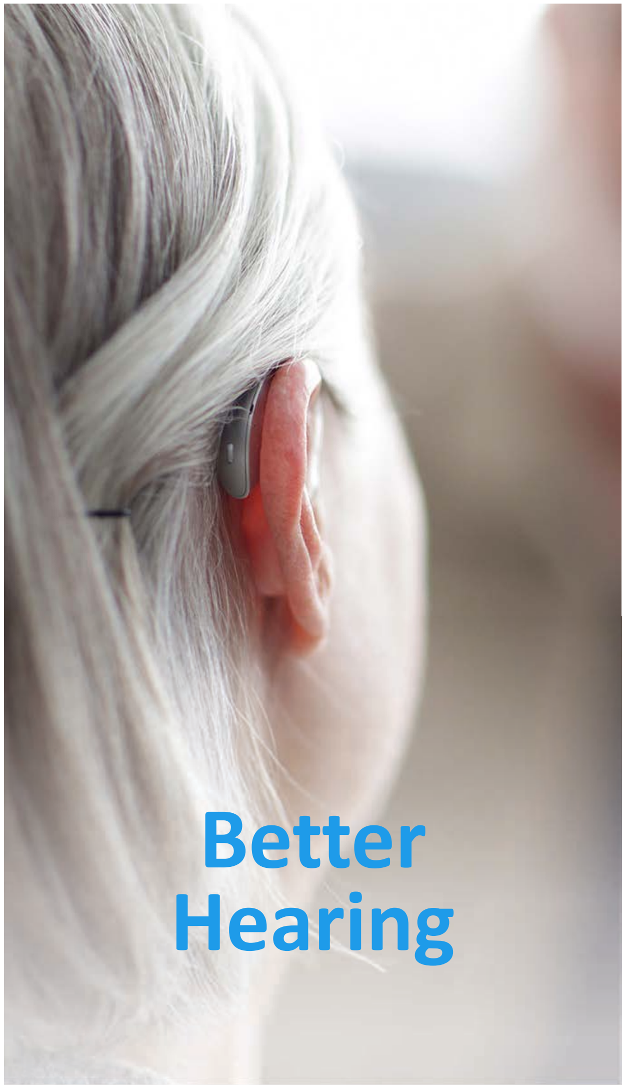
30-Second Chair Stand – strong relationship

More variability at lower stand counts

Significant mean difference of 0.8 stand count

Timed Up & Go – strong relationship

Time not calculated for 30 participants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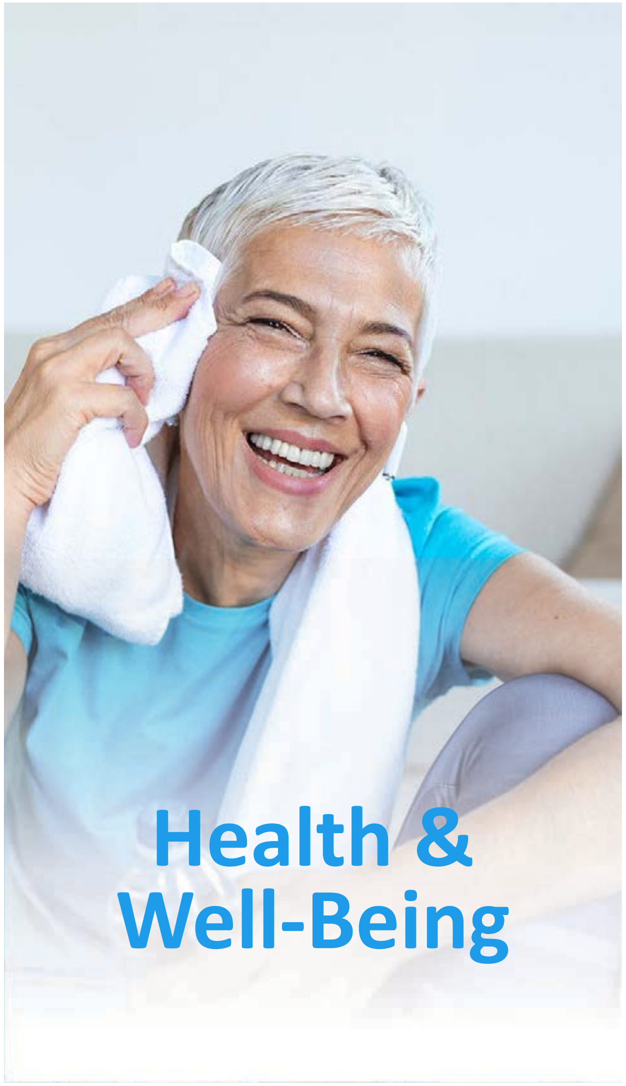
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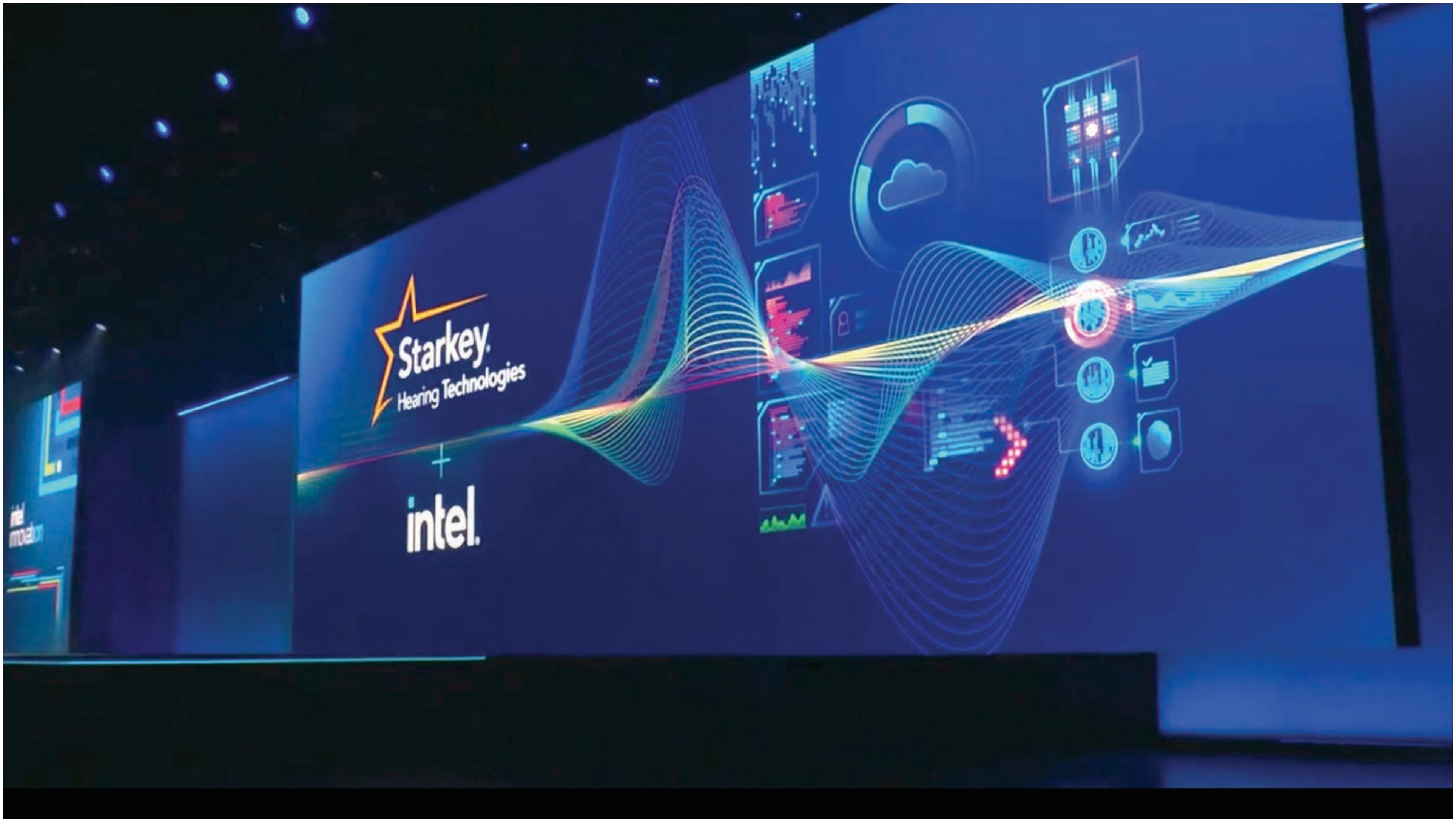

Starkey
Hearing Technologies
+
intel


Compute
Connectivity
Infrastructure
Artificial Intelligence
Ai
Sensing
Technology Superpowers
Enabled by Siliconomy

Conclusions

Use of AI has been increasing rapidly in hearing aids, in particular for improving speech-recognition in noise by combining machine-learning classification with listener "intent"

Health and wellness another opportunity; moving from fall detection to balance assessment screening and ultimately fall prevention

Intelligent assistant for use with PCs, mobile phones, and other applications to provide seamless integration of technology

Thank you

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