earlens

The Future of the Hearing Aid Industry: From Neurodegeneration to Hearables

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The Future of Hearing Aid Technology

Brent Edwards, PhD

Hearing aids have advanced significantly over the past decade, primarily due to the maturing of digital technology. The next decade should see an even greater number of innovations to hearing aid technology, and this article attempts to predict in which areas the new developments will occur. Both incremental and radical innovations in digital hearing aids will be driven by research advances in the following fields: (1) wireless technology, (2) digital chip technology, (3) hearing science, and (4) cognitive science. The opportunities and limitations for each of these areas will be discussed. Additionally, emerging trends such as connectivity and individualization will also drive new technology, and these are discussed within the context of the areas given here.

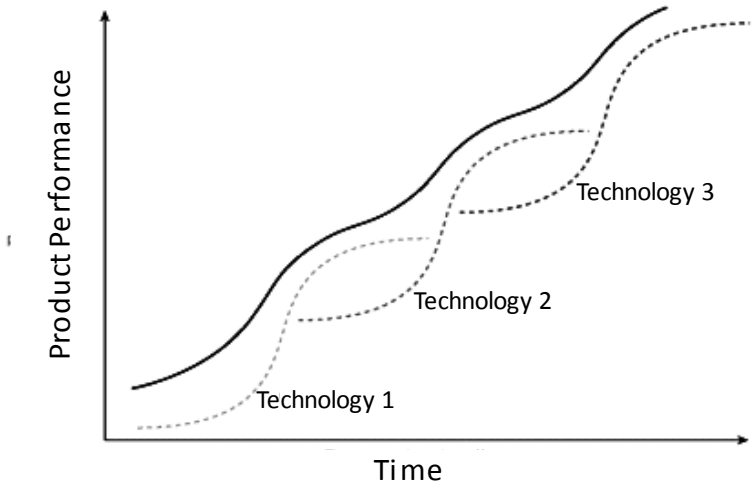
Keywords: hearing aid; digital; wireless; cognition

Edwards, 2007

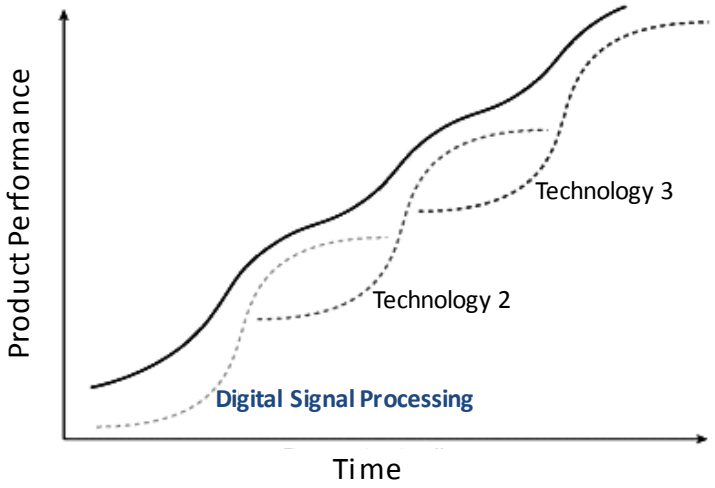
2005 Predictions

- Wireless technology will be the next wave
  - connectivity to consumer products
  - Ear-to-ear beamforming, synchronized compression
- Continued novel DSP algorithms
  - Frequency lowering, learning algorithms
- Cognition
  - Effect of hearing aids on cognitive ability
- Auditory Scene Analysis
  - Localization, source segregation

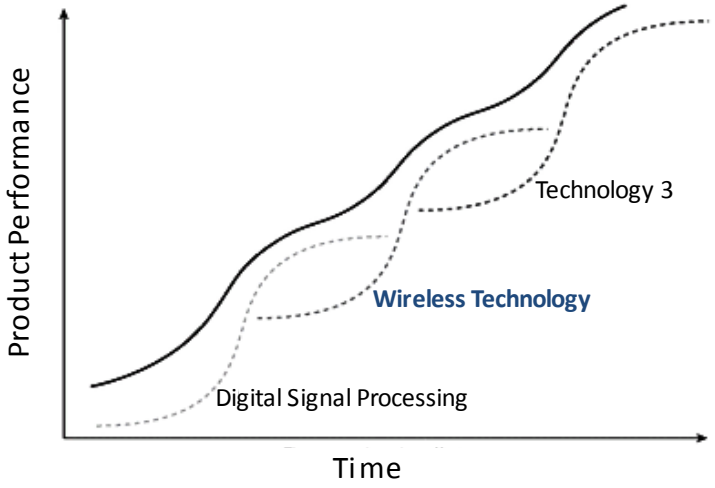
The Innovation S-Curve



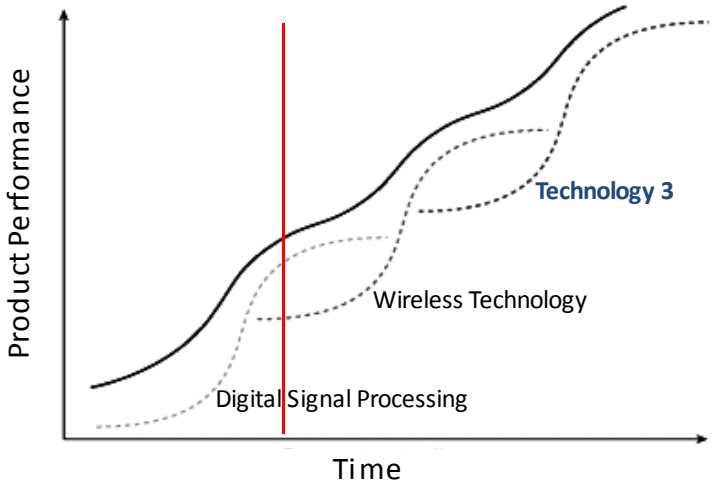
Hearing Aid Innovation

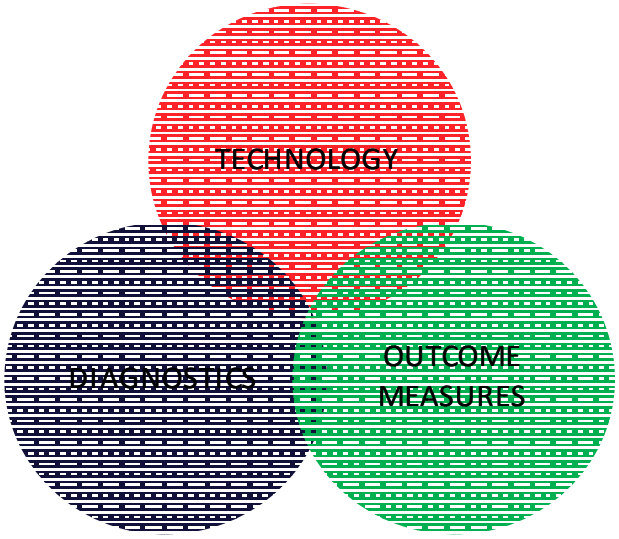


Hearing Aid Innovation



Hearing Aid Innovation





Relationship between audiogram and outcome measures

- Depends on outcome measure

Knudsen et al, 2010

	Outcome variable	# studies showing association with PTA
Intent … a lot	Help seeking	3 of 4
	HA uptake	3 of 3
Treatment … not much	HA use	1 of 6
	HA satisfaction	3 of 7

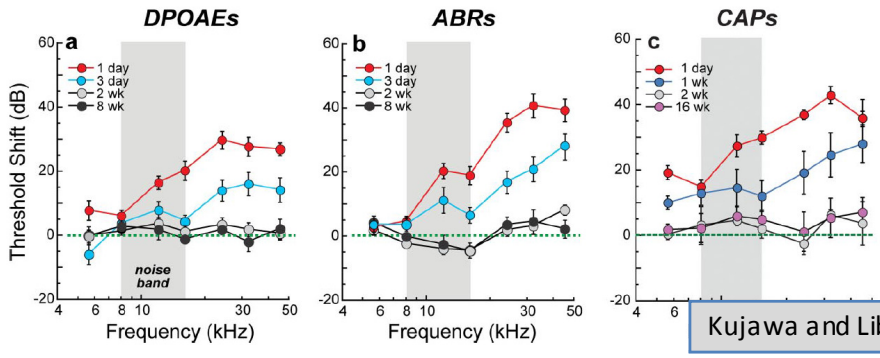
Naylor, 2014

SNR Loss Hypotheses

- Wider auditory filters
- Temporal jitter of auditory nerve impulses
- Poorer auditory scene analysis capabilities
- Poorer cognitive ability

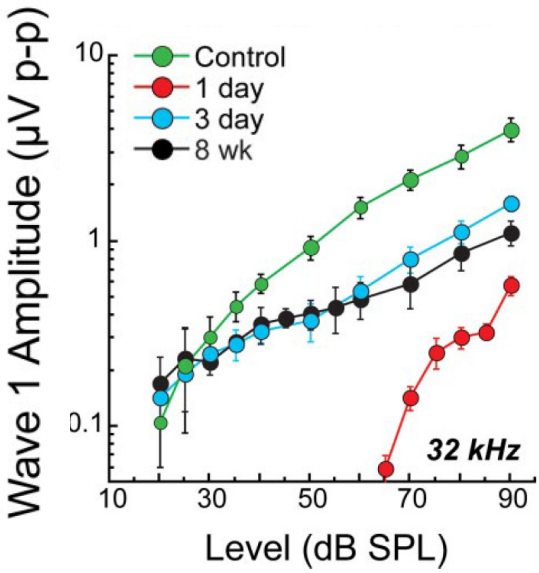
Neurodegeneration

- Noise exposed mice
  - 100 dB SPL, 2 hours
  - TTS but thresholds return to normal after 8 weeks



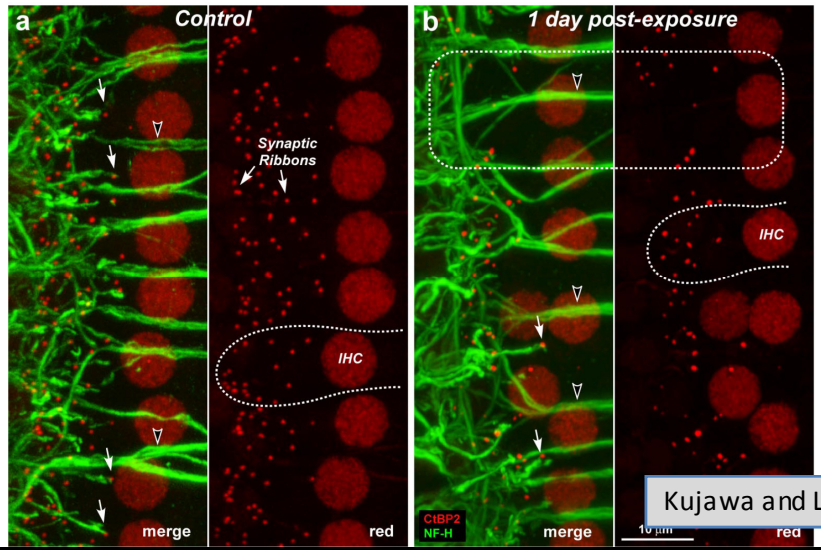
Kujawa and Liberman, 2009

ABRs At High Levels Do Not Return To Normal



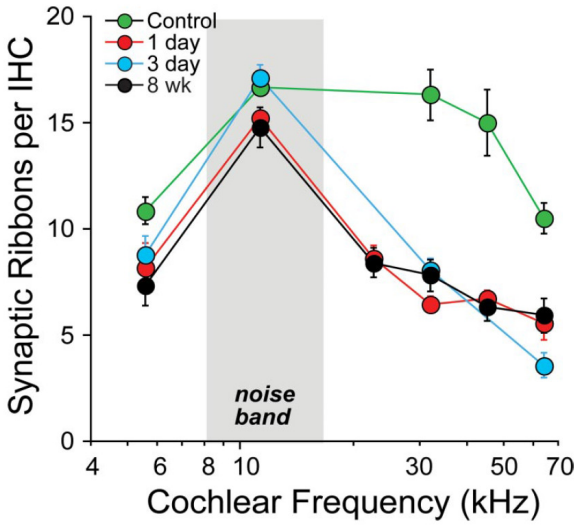
Kujawa and Liberman, 2009

Cochlear Nerve Dendrites and Synaptic Ribbons Destroyed



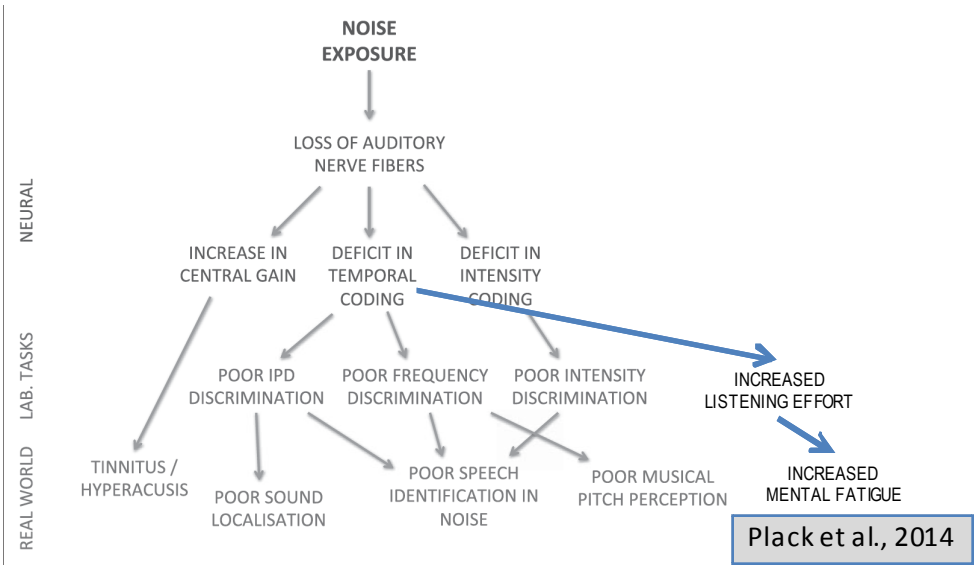
Kujawa and Liberman, 2009

Half of Synaptic Ribbons Are Destroyed



Kujawa and Liberman, 2009

Consequences of "Hidden Hearing Loss"

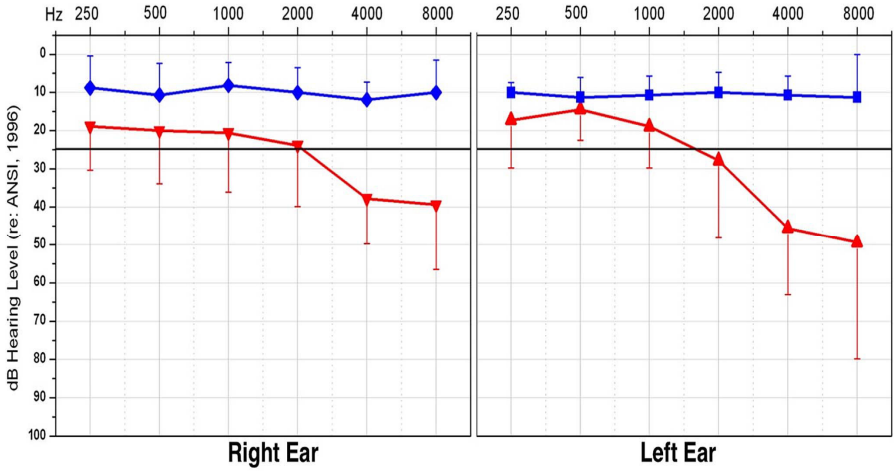


Plack et al., 2014

Questions

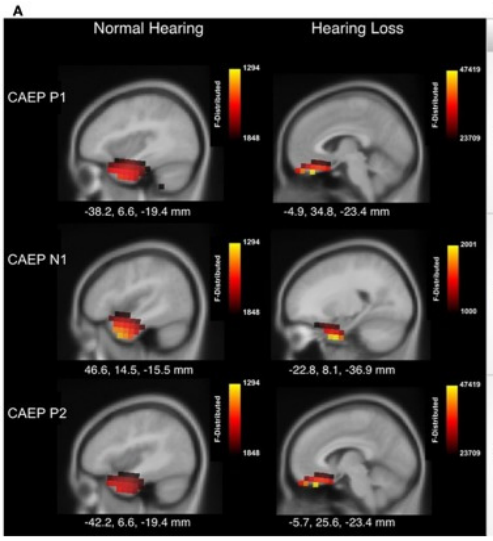
- How to diagnose neurodegeneration clinically?
- What unique interventions are needed to assist those with neurodegeneration?
- Are people with mild hearing impairment but significant neurodegeneration candidates for hearing aid technology?

Normal Hearing and Mild Losses



Campbell and Sharma, 2013

Neural Reorganization From Mild Hearing Loss

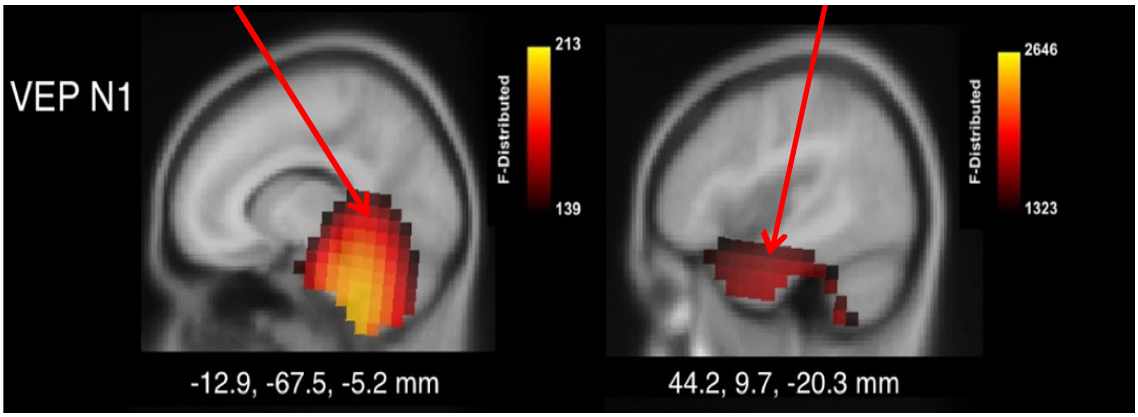


B

	Normal Hearing	Hearing Loss
CAEP P1	Medial Temporal Gyrus, Brodmann Areas 21, 38, Superior Temporal Gyrus, Fusiform Gyrus, Inferior Temporal Gyrus, Brodmann Area 20, Inferior Frontal Gyrus, Brodmann Area 47	Rectal Gyrus, Brodmann Area 11, Medial Frontal Gyrus, Brodmann Area 25, Superior Frontal Gyrus, Orbital Gyrus
CAEP N1	Medial Temporal Gyrus, Brodmann Area 21, Superior Temporal Gyrus, Inferior Temporal Gyrus, Brodmann Area 20, Brodmann Area 38, Fusiform Gyrus, Inferior Frontal Gyrus, Brodmann Areas 47, 13	Brodmann Area 36, Superior Temporal Gyrus, Brodmann Areas 38, 28, 47, 34, Inferior Frontal Gyrus, Medial Frontal Gyrus, Brodmann Area 11
CAEP P2	MedialTemporal Gyrus, Brodmann Area 21, Superior Temporal Gyrus, Brodmann Area 38, Inferior Temporal Gyrus, Brodmann Area 20, Fusiform Gyrus	Rectal Gyrus, Medial Frontal Gyrus, Orbital Gyrus, Brodmann Areas11, Superior Frontal Gyrus, Brodmann Areas 25, 32

Campbell and Sharma, 2013

Auditory Cortex Activation to Visual Stimuli



Normal Hearing

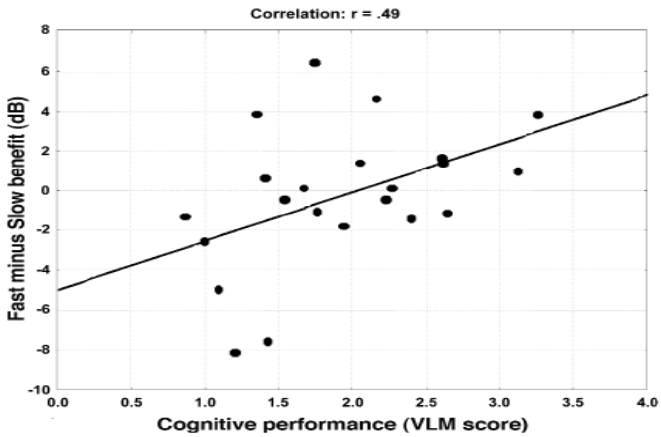
Hearing Impaired

Campbell and Sharma, 2014

Questions

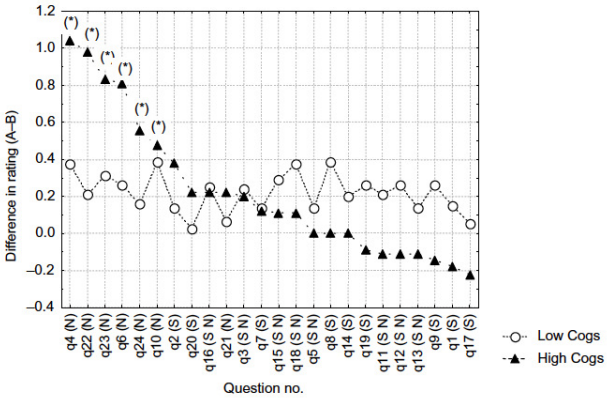
- What is the functional consequence of the auditory cortex reorganization?
- Can hearing aid technology reverse the reorganization?
- Again: are people with mild hearing loss candidates for hearing aid technology?

Cognitive Ability Affects Benefit From Technology



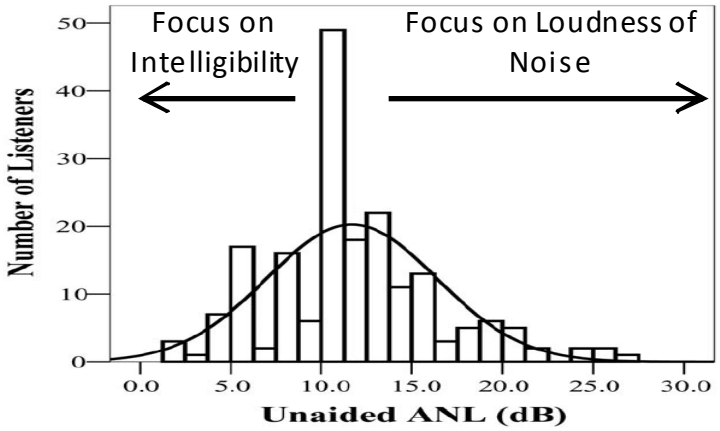
Lunner and Sundewall-Thorén, 2007

Hearing Aid Benefit More Salient for Higher Cognition Subjects



Lunner, 2003

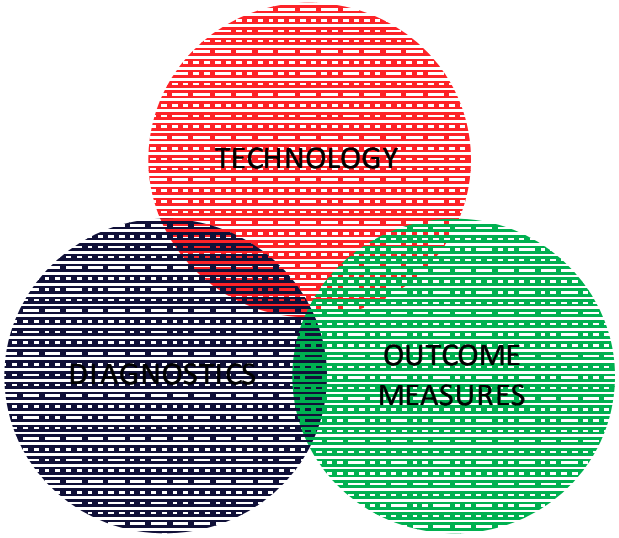
Acceptable Noise Level



Eddins et al., *in press*

Future of Diagnostics

- Diagnostics beyond the audiogram that can meaningfully help the clinician better treat their patient
- Diagnostics that address the clinician's limited time with patients
- Evidence that additional diagnostics produce meaningful improvements in treatment



New Technology Requires New Outcome Measures

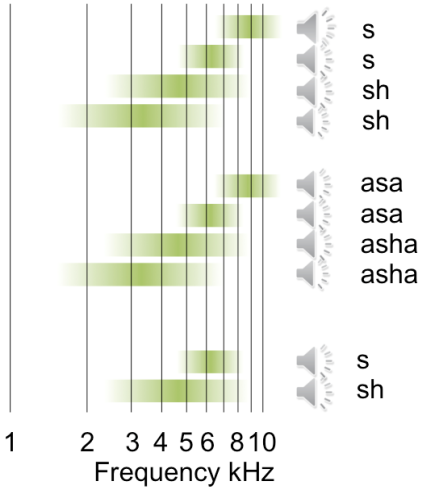
- Standard outcome measures not sensitive to benefit provided by new algorithms:
  - Frequency lowering
  - Adaptive directionality
  - Synchronized compression

Frequency Lowering

Detection test
Above which level are the test sounds audible?

Recognition test
Above which level are audible test sounds intelligible?

Distinction test
How discriminable are audible test sounds?



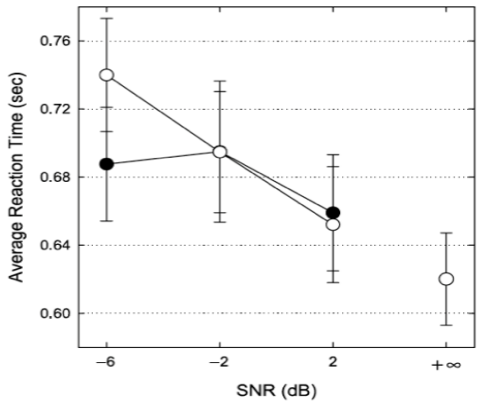
Boretzki and Schmidt, 2013

Haubold, Schmitt (2012): Different Frequency Lowering Principles

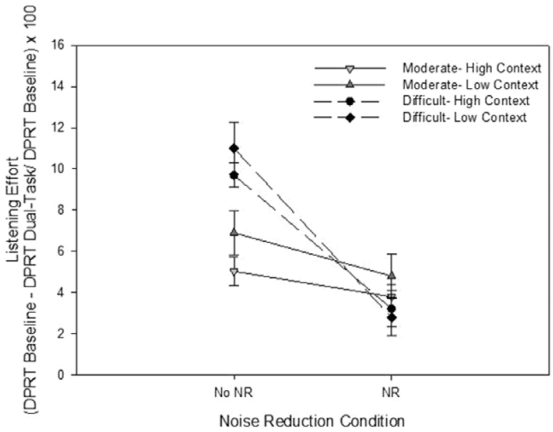
Frequency lowering	none	none	off	on	off	on	off	on
Product	none	A	B		C			

Boretzki and Schmidt, 2013

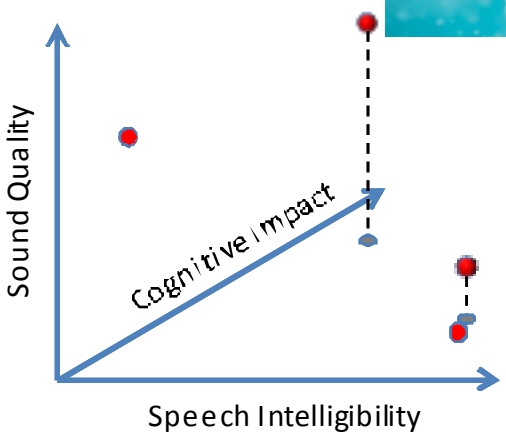
Technology Reduces Cognitive Load

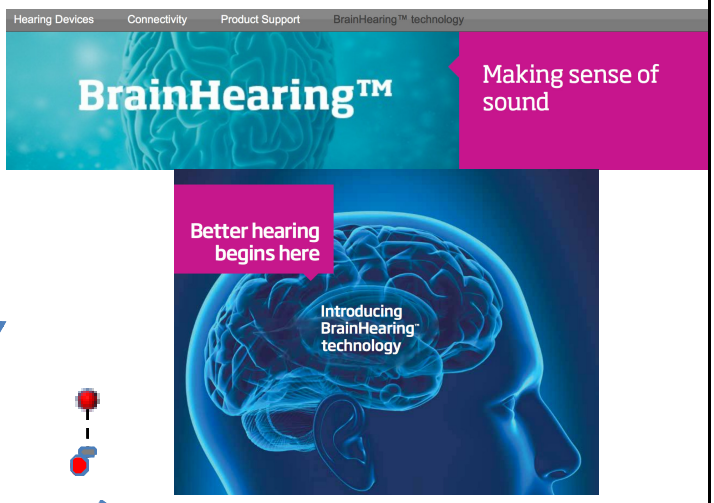


Sarampalis et al., 2009



Desjardins and Doherty, 2014





Laboratory Performance Not Representative of the Real World

72 SEMINARS IN HEARING/VOLUME 26, NUMBER 2 2005

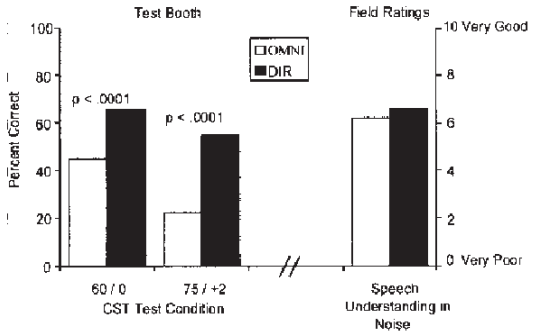
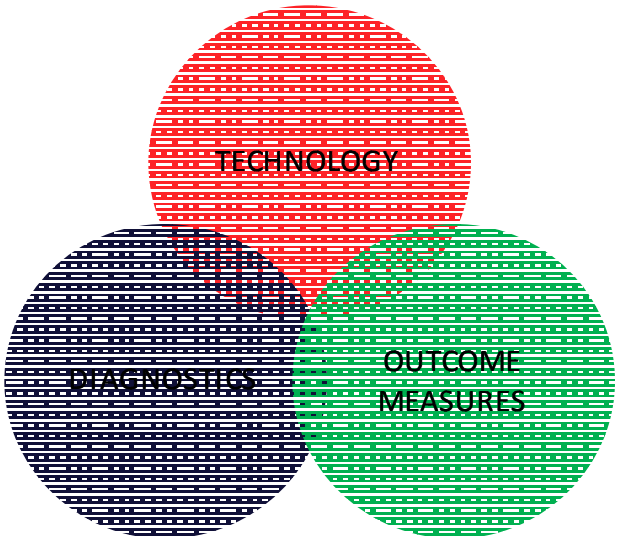


Figure 1 Comparison of (left) the directional advantage obtained in an audiometric test booth under two test conditions to (right) field ratings of speech understanding in background noise for the two microphone modes. OMNI, omnidirectional; DIR, directional.

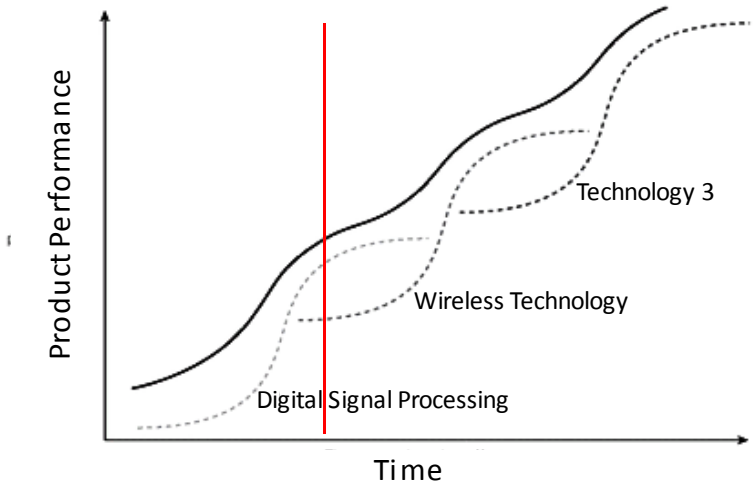
Walden et al., 2005

Future of Outcome Measures

- Look for new laboratory outcome measures to demonstrate benefit of new technology
- Look for outcome measures that represent the real world experience

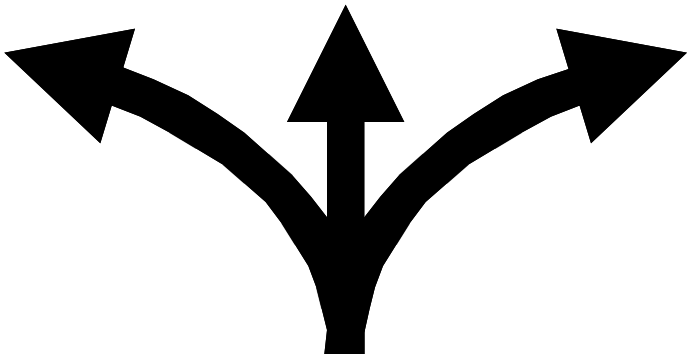


The Innovation S-Curve

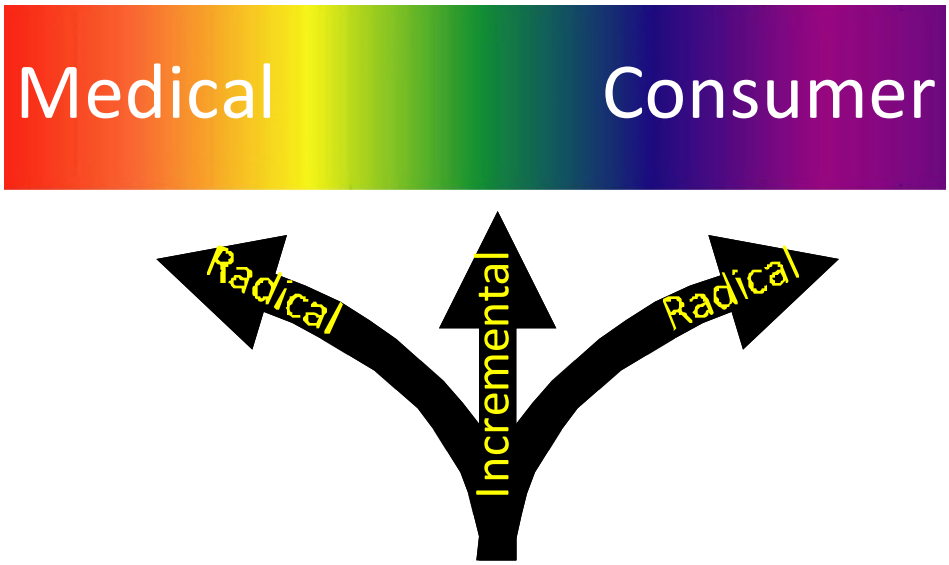


Innovation

Innovation



Innovation



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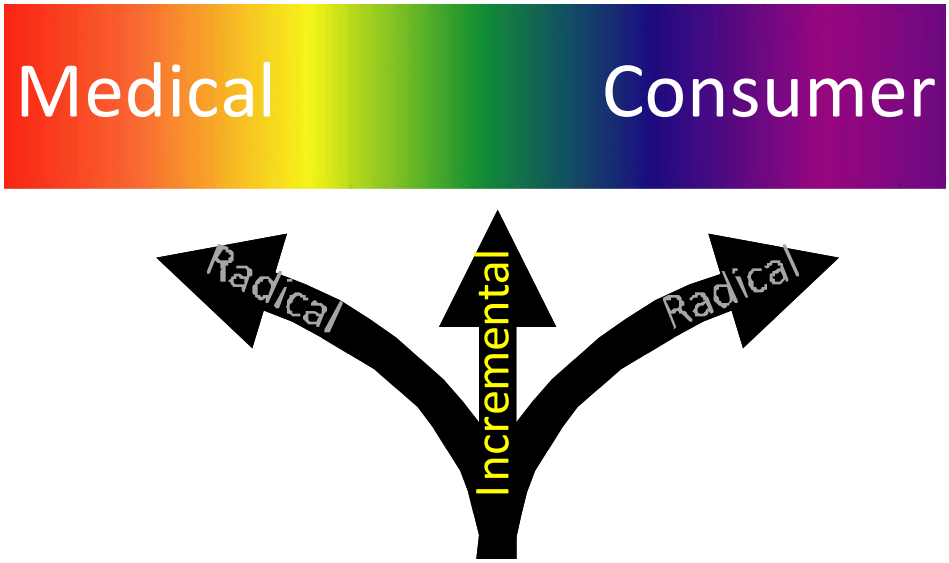
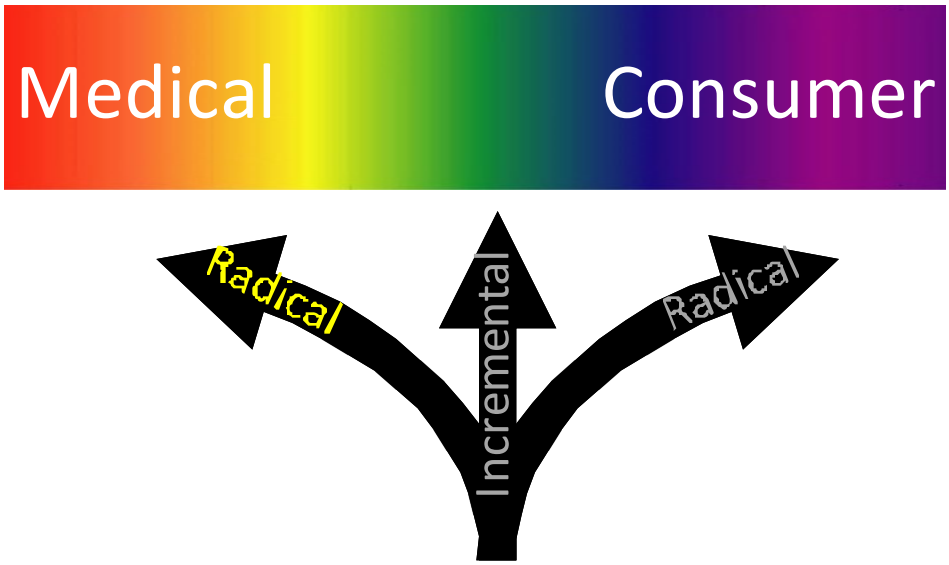


Innovation



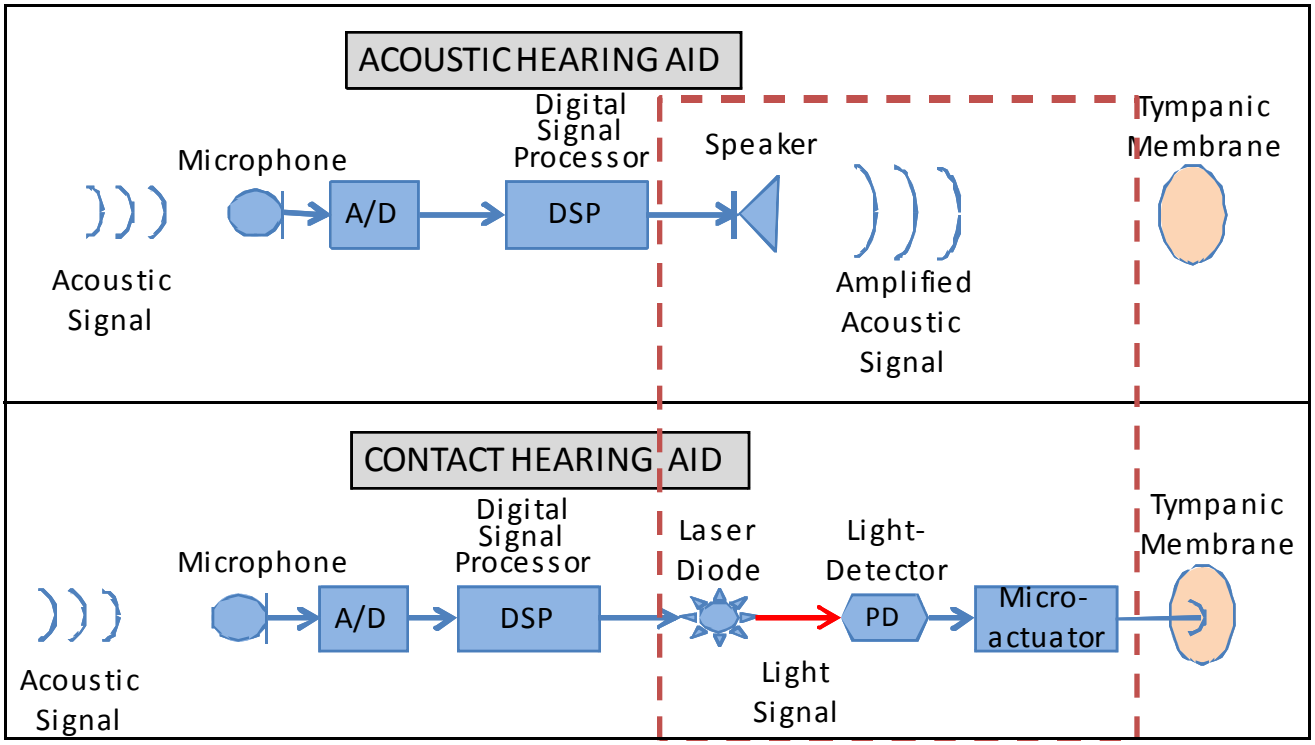
What is the most fundamental function of a hearing aid?

Provide Audibility

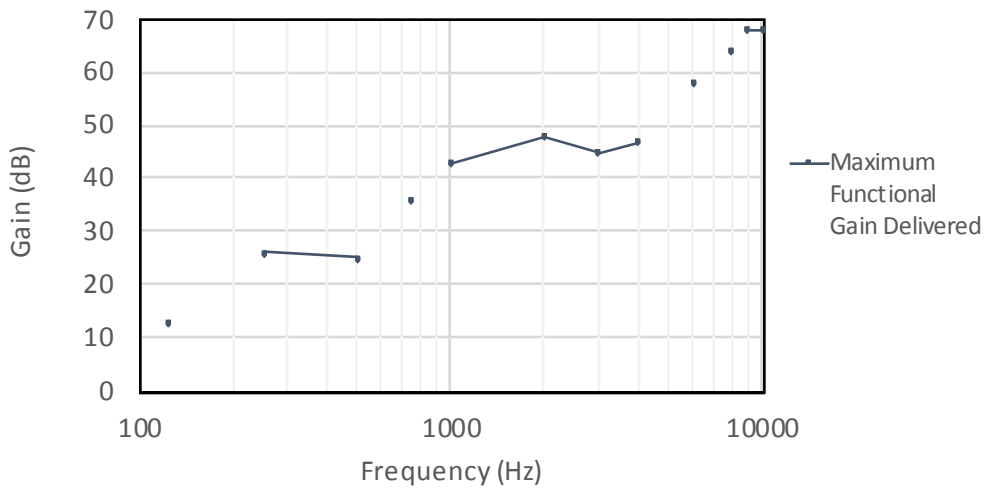
Hearing Aid Limitations

1. Limitations on High Frequency Audibility
2. Limitations on Low Frequency Audibility
3. Limitations on Maximum Gain

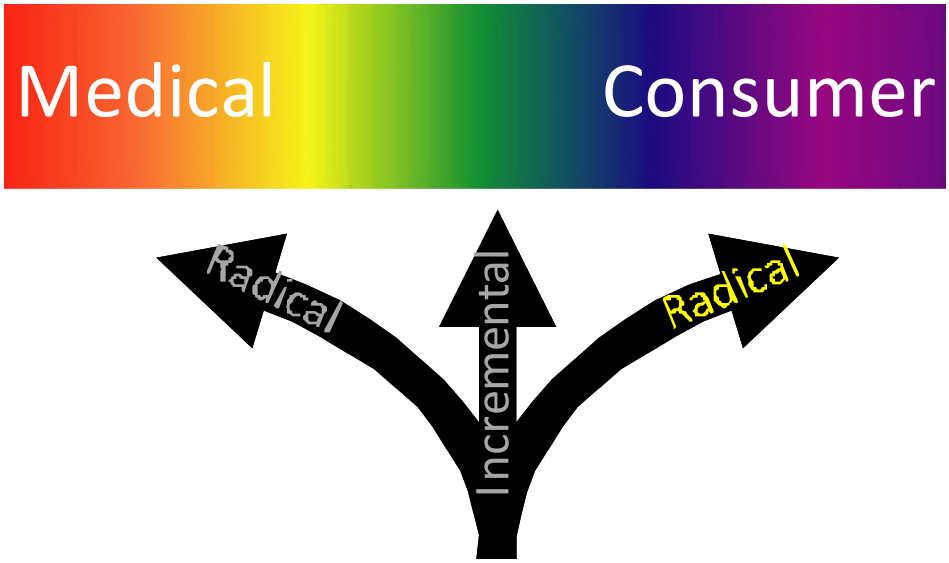
41



Maximum Gain Provided in a 43-Subject Clinical Trial



Innvovation



Implications of Digital Health

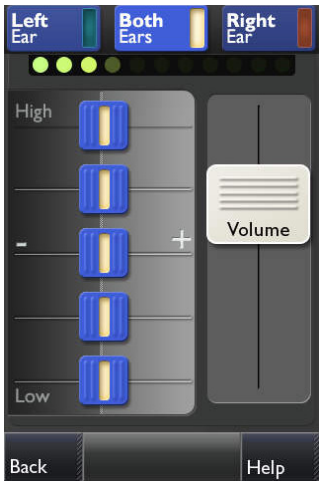
Sophisticated Technology & UI

Sophisticated Expert System

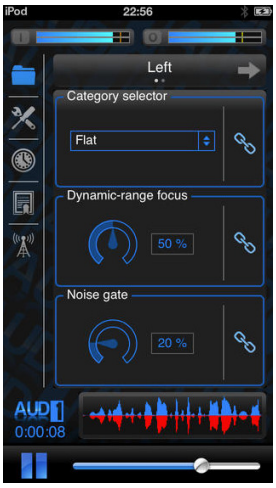
Nurse Practitioner

Portability & Low Cost

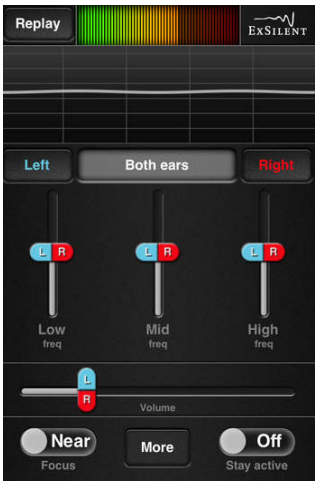
Apps With Hearing Aid Functionality



SoundAmp



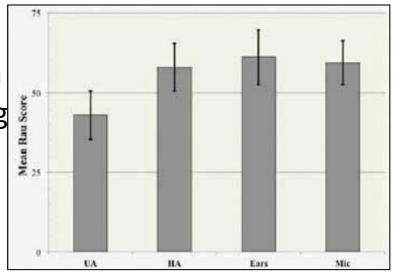
Aud1



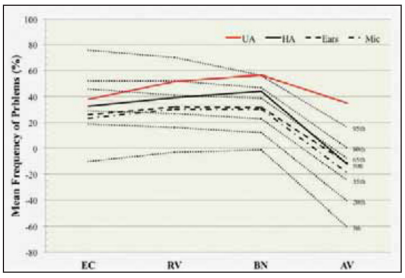
HearYouNow

Apps Perform Similarly To Hearing Aids

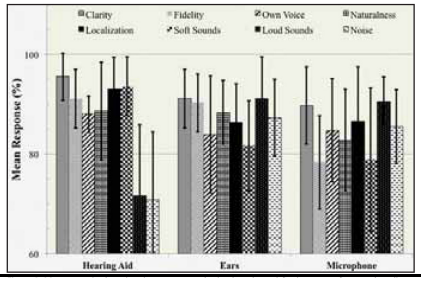
Same speech understanding



Better benefit ratings

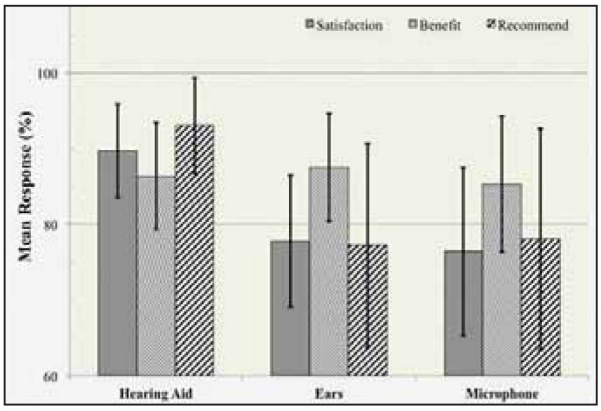


Similar or better subjective benefit



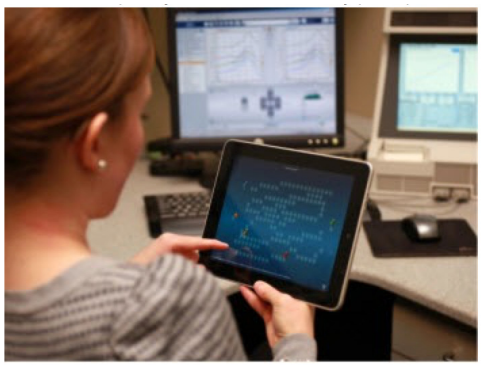
Amlani et al., 2013

But Subjects Overwhelmingly Prefer Hearing Aids



Amlani et al., 2013

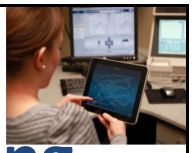
Self Fine-Tuning Apps

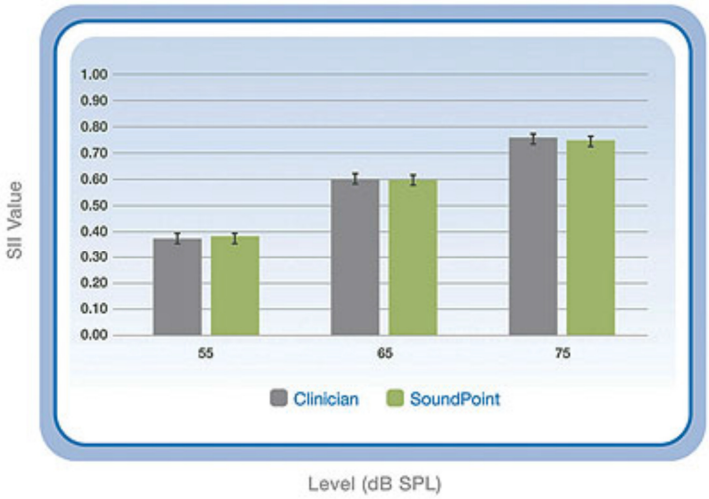


SoundPoint

EarMachine

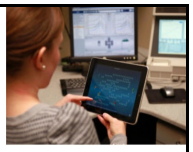
Self-fitting Produces Similar Intelligibility to an Audiologist Fitting

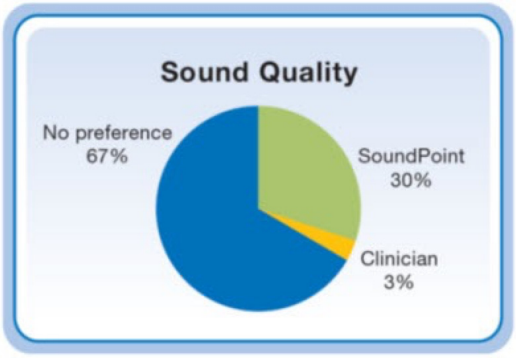


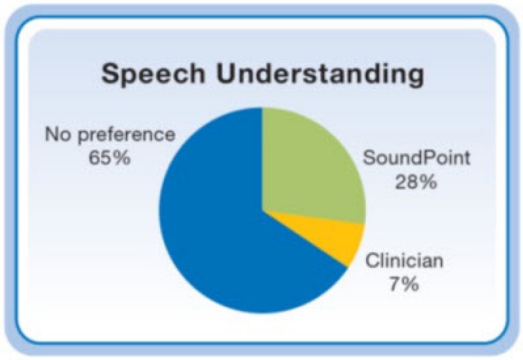


Valentine et al., 2013

Self-fitting Preferred Over an Audiologist Fitting

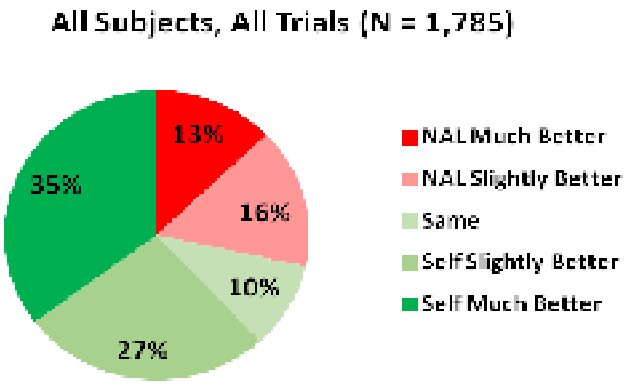






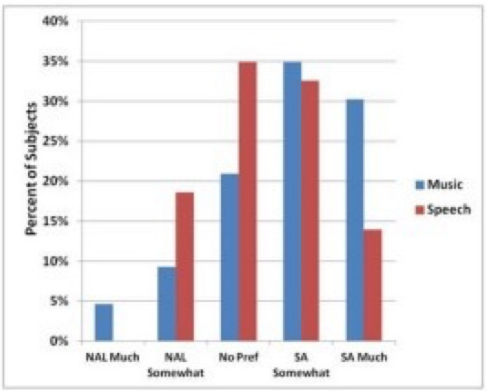
Valentine and Dundas, 2013

Blind Comparison of Own Settings with NAL-NL2



Van Tasell and Sabin, 2014

Self-Fitting Better With Music



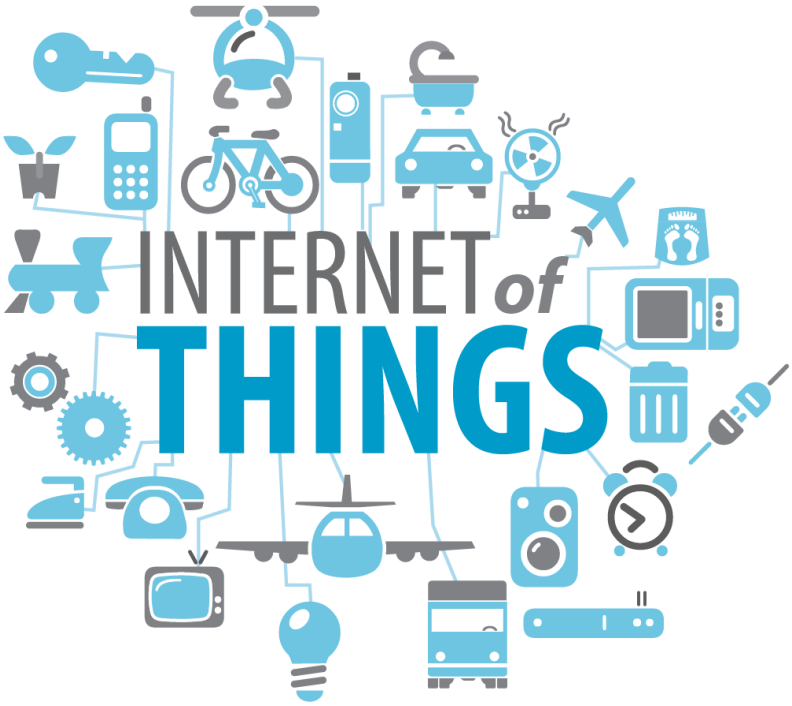
41 subjects' blind comparison preference ratings of NAL-NL2 prescribed settings vs. their self-adjusted (SA) settings using Ear Machine controllers.

Van Tasell and Sabin, 2014

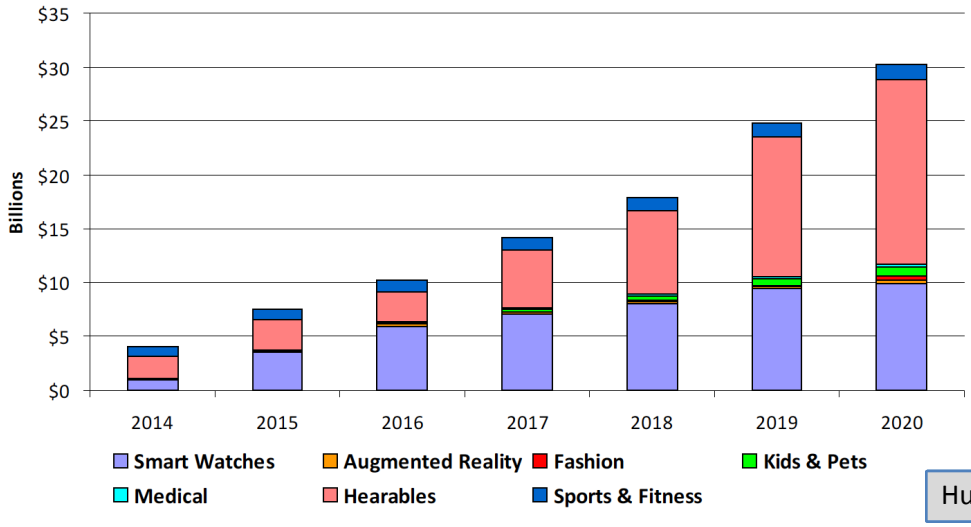
Your App Will See You Now

http://www.wsj.com/articles/the-future-of-medicine-is-in-your-smartphone-1420828632

- Apps have the potential to:
  - Allow for patient fine-tune in the real-world
  - Offload clinician's time for diagnostics
  - Measure outcomes in the real-world



Projected Global Revenue for Wearables

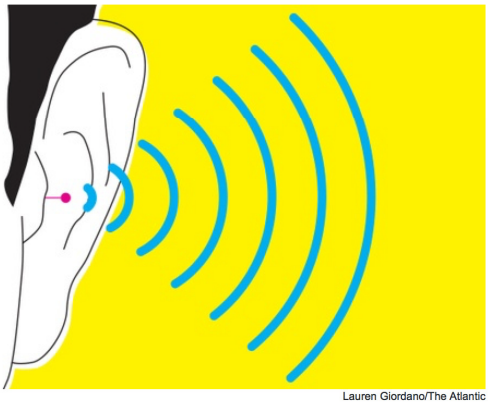


Hunn, 2014

What My Hearing Aid Taught Me About the Future of Wearables

As human-enhancing technology becomes tinier and more advanced, the price of progress is complexity.

RYAN BUDISH | FEB 5 2015, 10:31 AM ET



Lauren Giordano/The Atlantic

Six Wearables To Enhance The Wearable Revolution In 2015

WT VOX

FITNESS WEARABLES, WEARABLE SMARTWATCHES AND WRISTBANDS, WEARABLES FOR KIDS

6 Wearables That Will Enhance The Wearable Revolution In 2015

Share on Twitter Share on Facebook

26/01/2015

Siemens Hearing Aid

Hearing aids are one of the most common wearables, and yet often overlooked for flashier newer devices

How Google Glass will Disrupt the Hearing Aid Industry? | World Future Society

How Google Glass will Disrupt the Hearing Aid Industry?

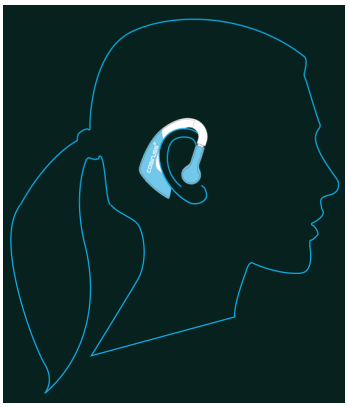
Posted on April 26, 2013

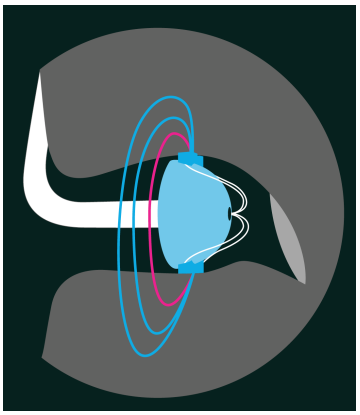
Subject(s):

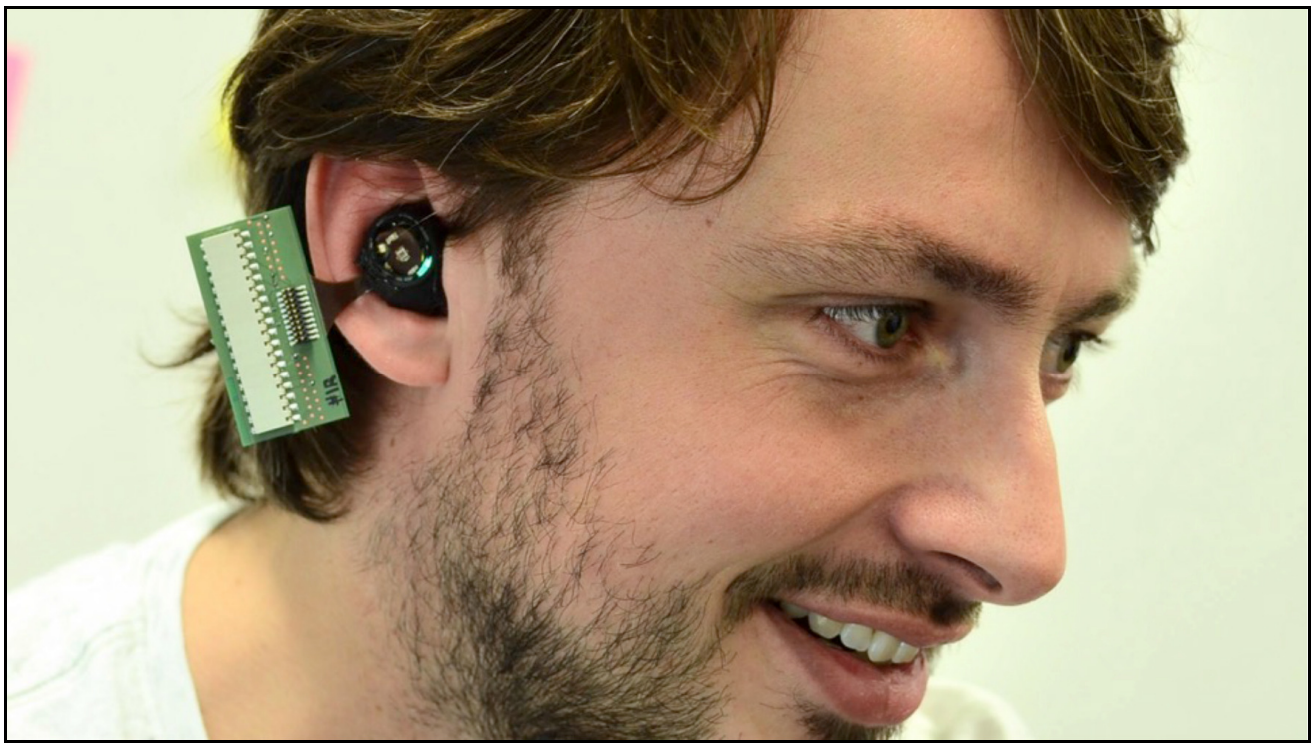
Hearable from Cosinuss

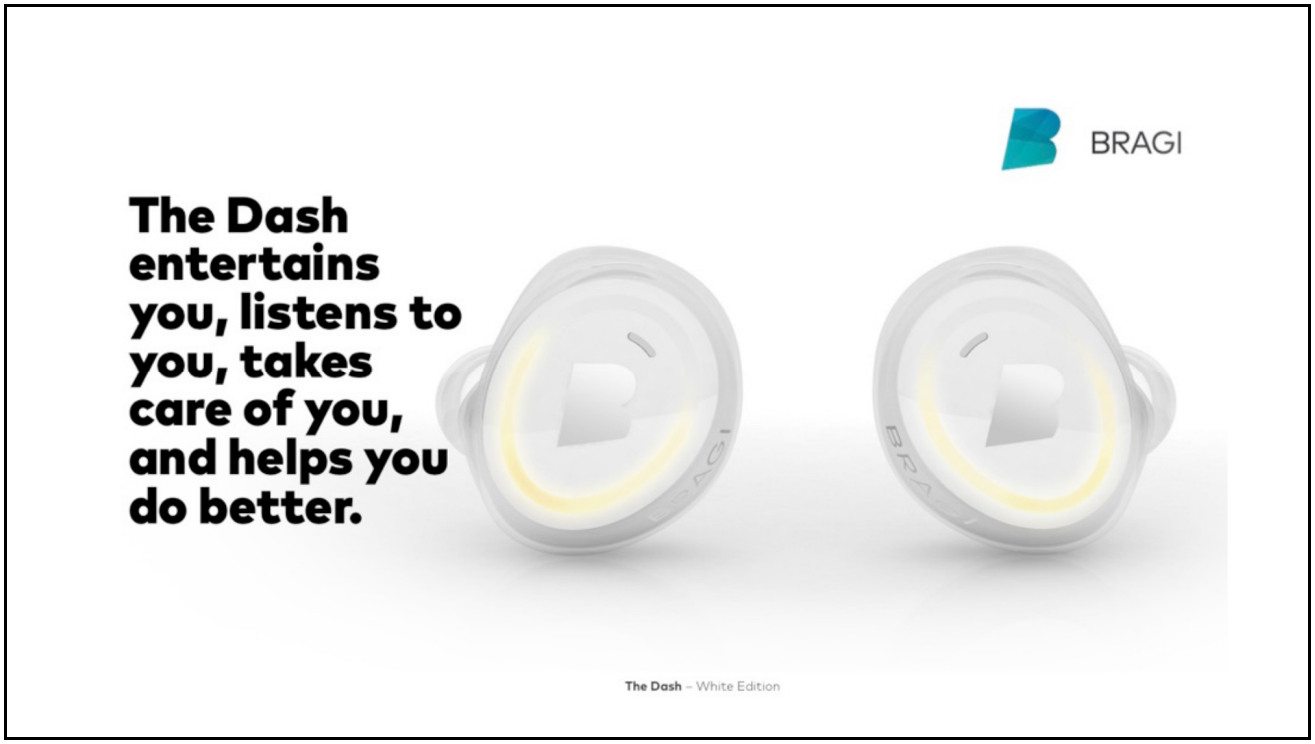
Hearable that measures:

- BPM
- HRV
- SpO_2
- °C
- # of Steps

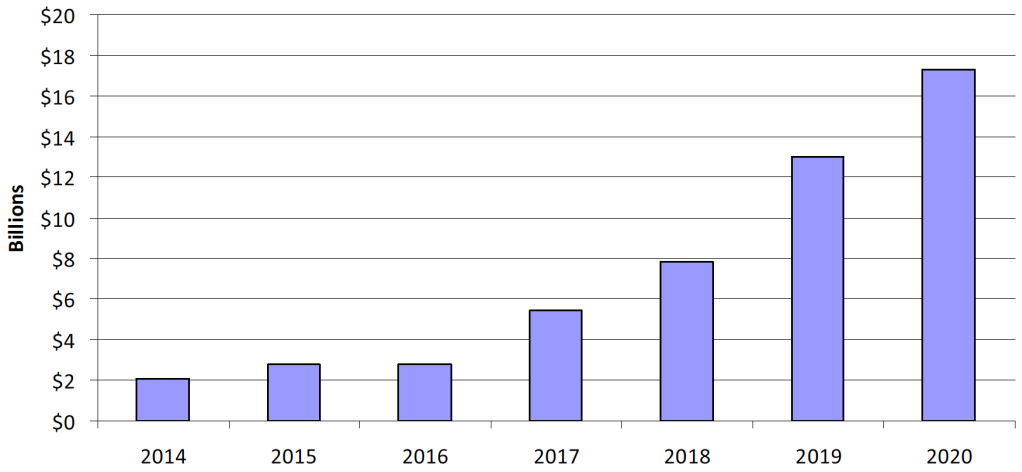






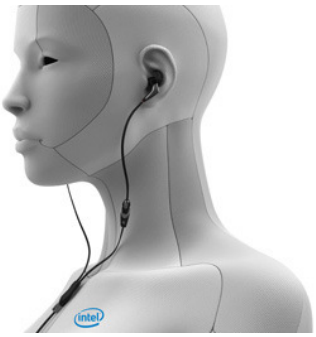

BRAGI
The Dash entertains you, listens to you, takes care of you, and helps you do better.
The Dash – White Edition

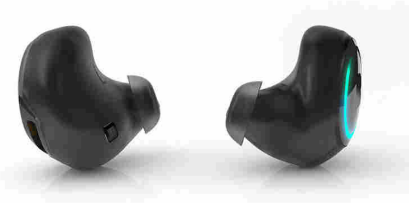
Projected Global Revenue for Hearables



Hunn, 2014

Hearables





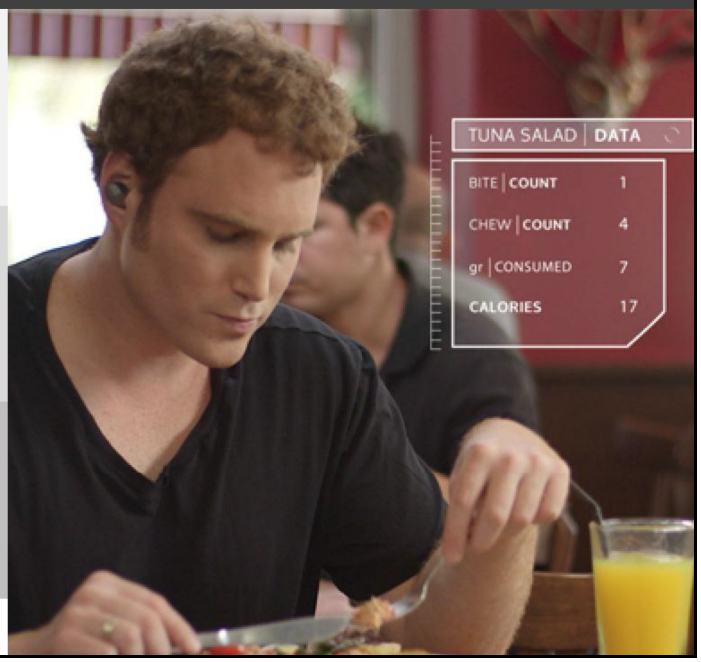
Our Solution: BitBite

BitBite listens to the way you eat

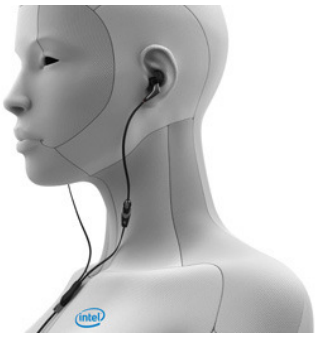
Builds a multivariate model for assessing your individual eating patterns

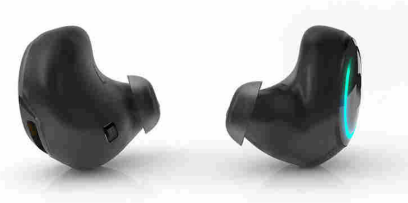
Coaches you until your goal is reached

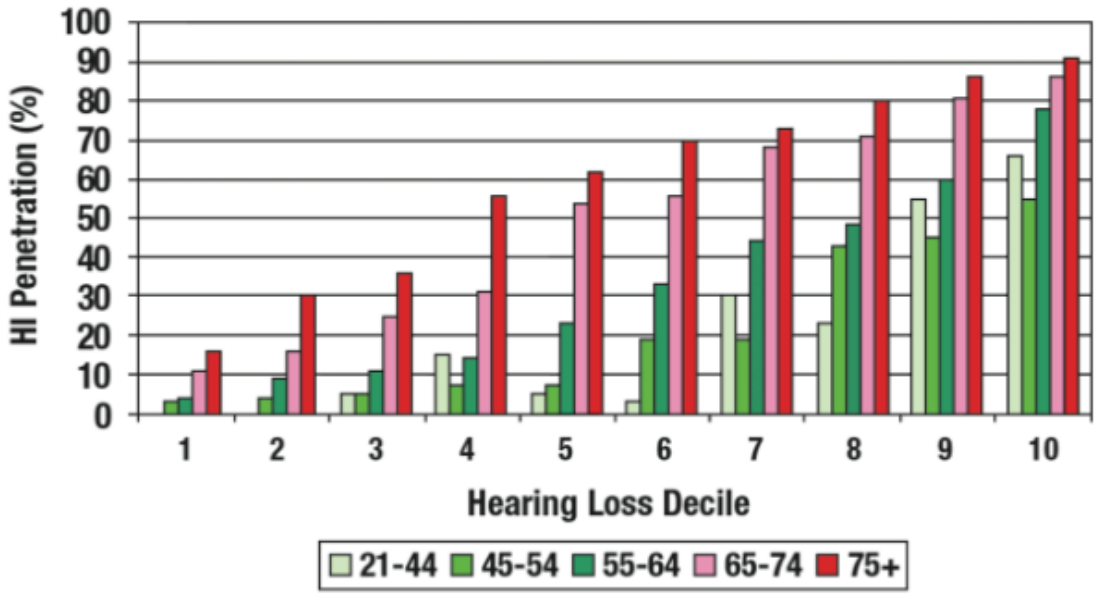
BitBite

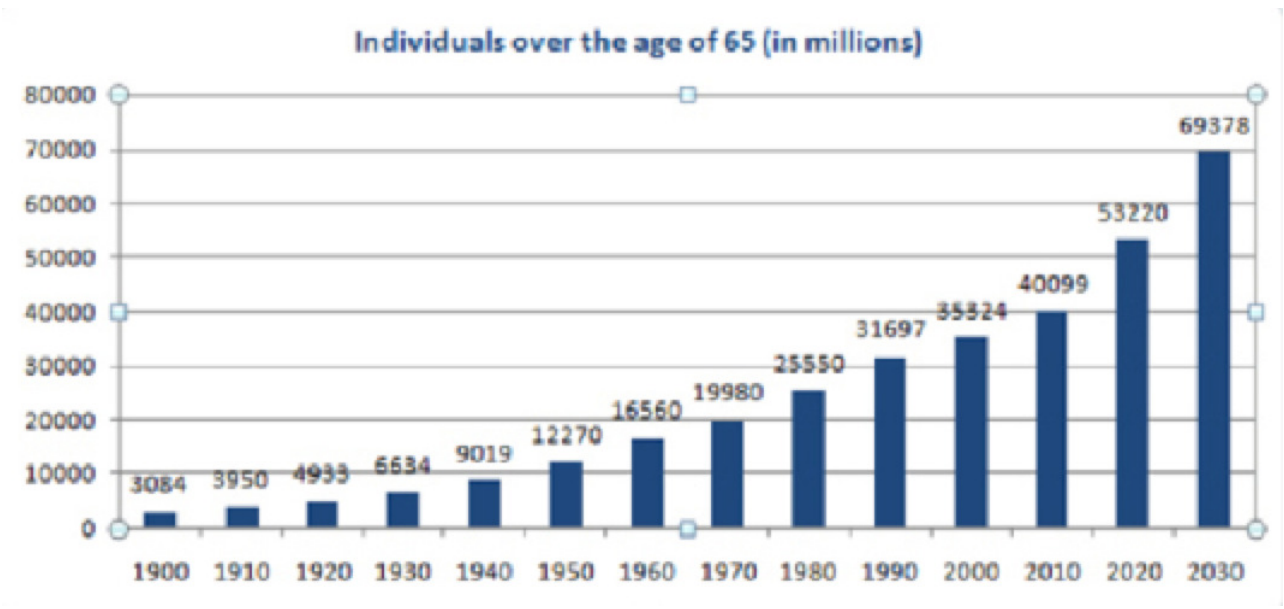


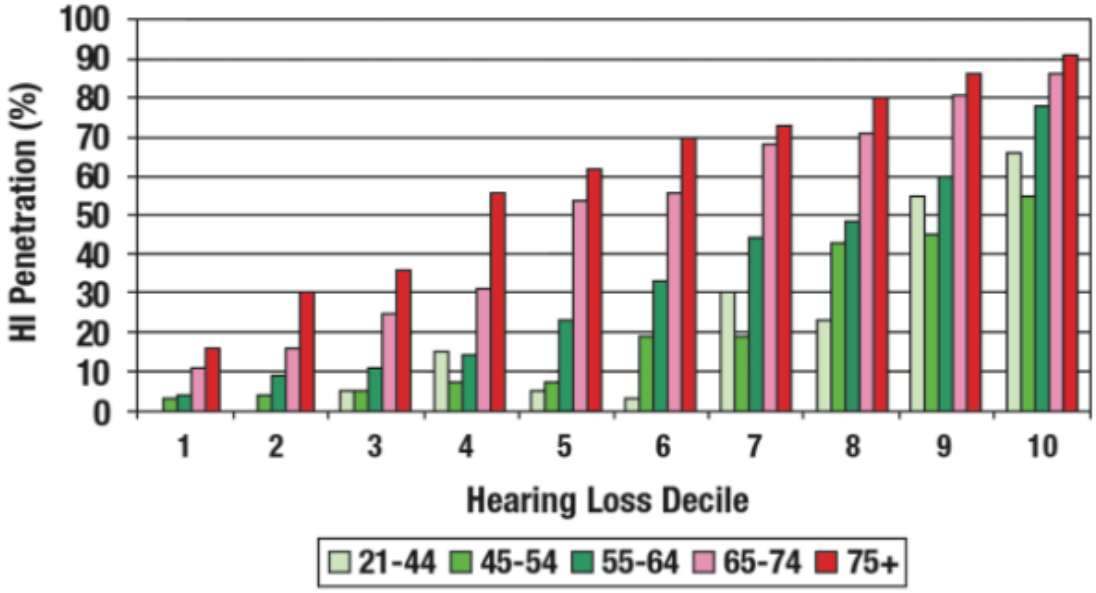
Earables





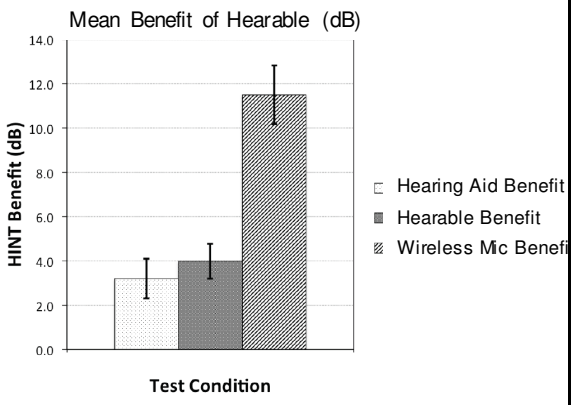

HI Penetration (%)
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Hearing Loss Decile
21-44
45-54
55-64
65-74
75+


Individuals over the age of 65 (in millions)
80000
70000
60000
50000
40000
30000
20000
10000
0
3084
3950
4933
6634
9019
12270
16560
19980
25550
31697
35524
40099
53220
69378
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030

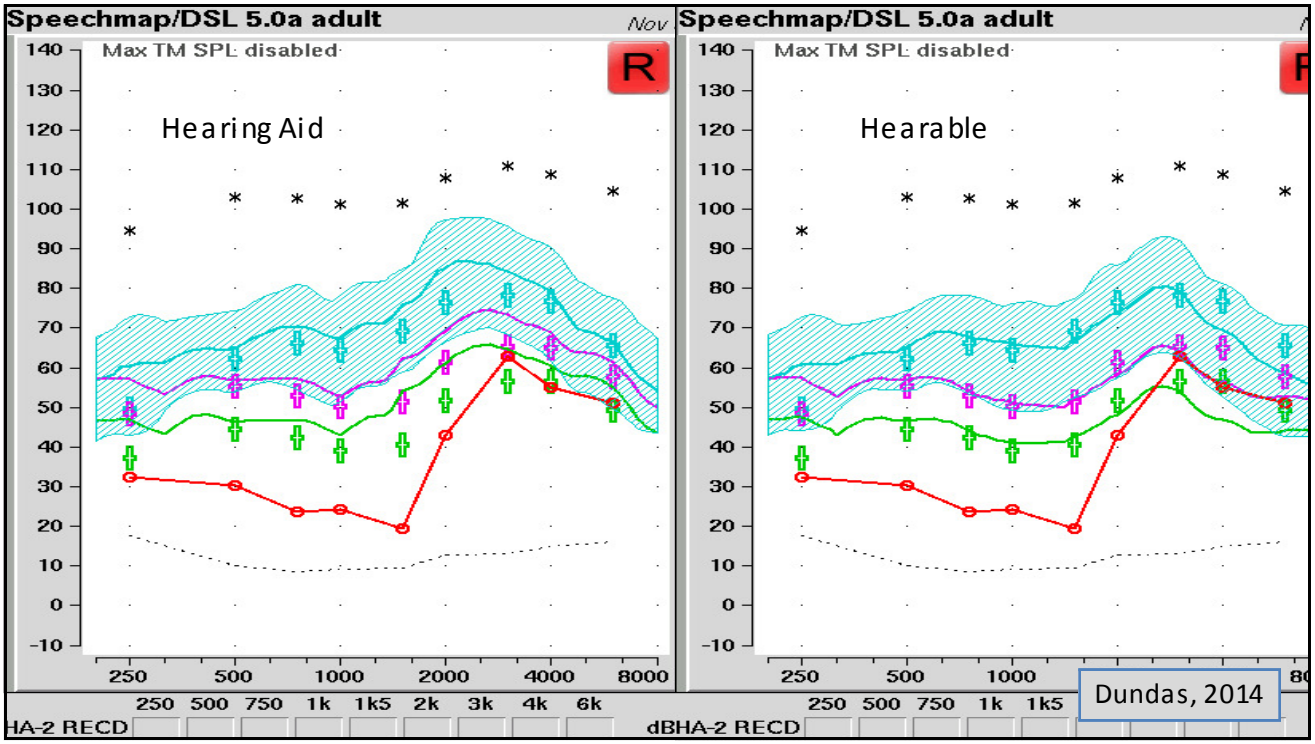

HI Penetration (%)
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Hearing Loss Decile
21-44
45-54
55-64
65-74
75+

AT&T
12:00 PM
100%
Done
Dining
To tune: tap and listen.
BOOST
FULL
BRIGHT

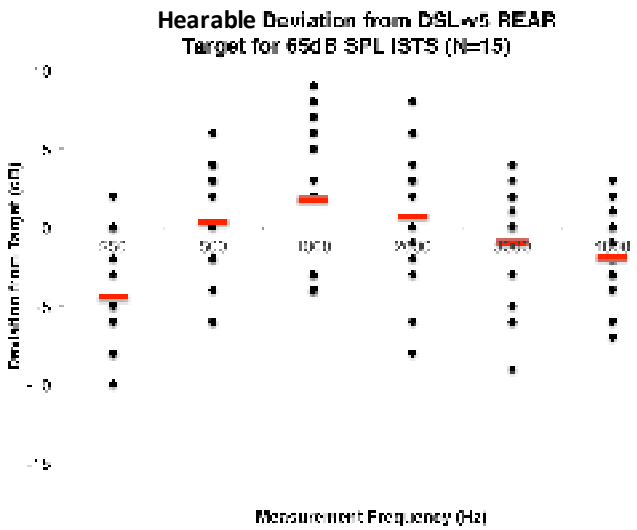
- Aided HINT re: unaided
  - RIC hearing aid
  - Hearable earpiece
  - Hearable wireless microphone



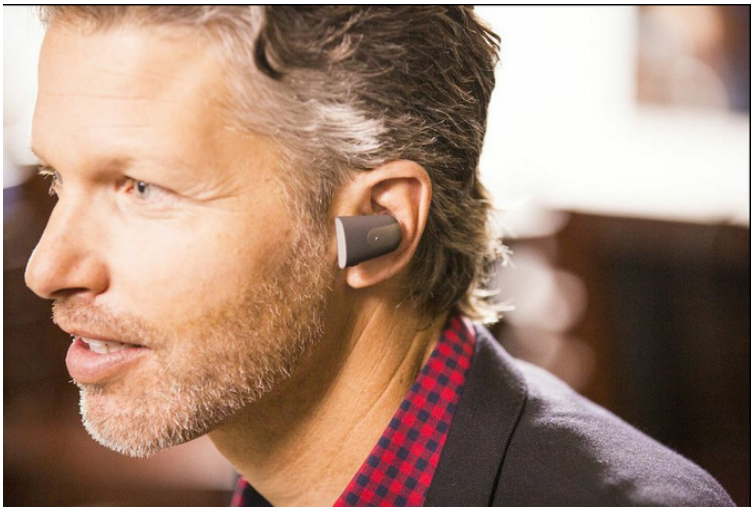
Dundas, 2014

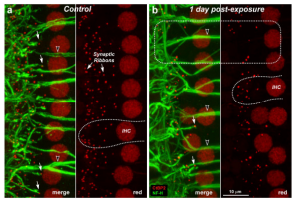


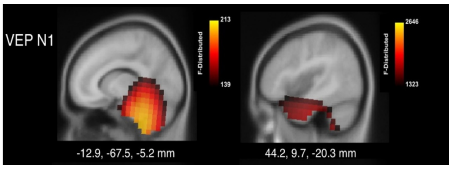
Dundas, 2014



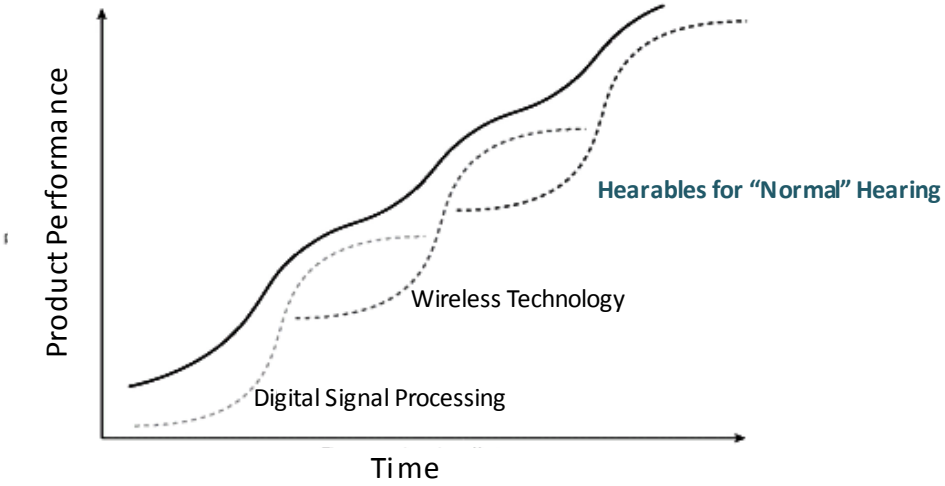
Dundas, Unpublished



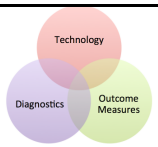




Hearing Aid Innovation



Summary



Diagnostics

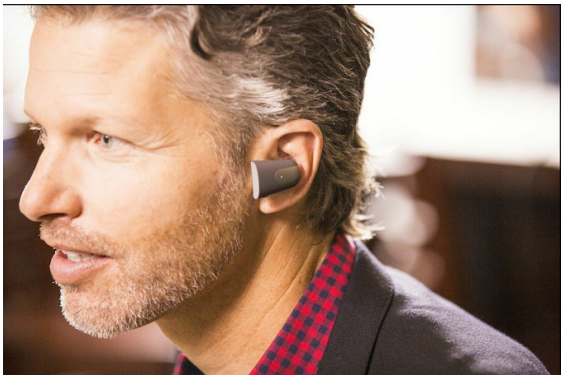
- Move beyond the audiogram
- New definitions of normal and impaired hearing

Outcome Measures

- New outcome measures for new technology
- New outcome measures with real-world validity

Technology

- Incremental innovation will continue, particularly wireless
- Patient-enabling technology can be a valuable tool for audiologists
- Convergence with Hearable technology is inevitable



Thank you!

bedwards@earlenscorp.com

@bwedwards