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Making the Case for Custom

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Allied Health Media AudiologyOnline

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Making the Case for Custom

AudiologyOnline 2014 NIHL Expert Seminar Series

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Noise-Induced Hearing Loss Seminar Series 2014

Wed July 2, 2014: 8-9am
Brian Fligor, ScD
Making the Case for Custom

Wed July 16, 2014: 10-11am
William H. Martin, PhD
Tinnitus Care: What Should I Know When Starting To Provide Tinnitus Care

Wed July 23, 2014: 12-1pm
Jeffrey M. Ellenbogen, MD
Sound Sleep on Noisy Nights: The Influence of Noise on Sleep Quality

Wed July 30, 2014: 12-1pm
Robert Ghent, AuD
Management of Hearing Loss Prevention in Live Entertainment

Making the Case for Custom

Disclaimer:

The views expressed herein are mine, based on 14 years of practice of audiology fitting custom hearing protection, consumer earphones, in-ear monitors, and hearing aids to musicians and music enthusiasts. These views are not intended to reflect the views of my employer, Lantos Technologies. Any representation of benefits of custom-fitted devices are for educational purposes, and not intended as promoting any particular company.

Agenda

- Introduction of Pros and Cons of Custom for Hearing Protection and Consumer Earphones
- At risk-populations, how much risk
- Acoustics: non-custom and custom
- Influence of earphone isolation on chosen listening level
- Economics of custom
- Utility of custom in NIHL Treatment
- Take-home messages

Making the Case for Custom

Why aren't ALL devices in the ear custom!?

- ✓ There is good evidence that "custom" hearing protection devices and consumer earphones (and hearing aids) perform better than non-custom devices
- ✓ Custom *should* be more comfortable and secure
- ✓ Custom personalizes the device (and the care)
- ✓ Custom is potentially another revenue stream

Making the Case for Custom

Barriers:

- ✓ Custom requires additional resources (time, equipment), and may involve exposure to risk (audiologist and patient)
- ✓ Custom is not *always* more comfortable
- ✓ Non-custom is easier to commoditize
- ✓ Non-custom might be *good enough*/custom might not be so much better

Result: low adoption rate for custom in hearing protection device (HPD) and consumer earphones

Populations at Risk

Occupational noise exposure (unwanted byproduct)

- U.S. mandated in Hearing Conservation Programs for all workers exposed to ≥ 90 dBA, 8-hr TWA (offered to all workers exposed ≥ 85 dBA, 8-hr TWA)
- 9 million workers in the U.S.; 40 million worldwide
- Education and Motivation component of HPD use
  - NIHL *still* amongst highest incidence work-related injuries (11.8% of non-fatal injuries in 2011; Bureau of Labor Statistics, 2012)
- EPA rating of HPD performance (e.g., "NRR"): de-rating for effective hearing protection (variability)
- NRR vs. NRR_{SF} and move to Field PAR/f-MIRE measures

Populations at Risk

Music exposures (intent of the activity)

- Portable listening devices (PLD) 103 – 121 dBA (FFE)
  - 250 million smartphones worldwide
  - 15-50% exceed L_{Awkn} ≥ 85 dBA (equivalent continuous level)
- Concert attendance: 103 – 112 dBA L_{A8hn} (~5000% dose)
- Musician (amplified) stage levels 100 – 110 dBA
  - Highest adoption of full-custom (in-ear monitors) – pro musicians
- Orchestral, drum corp, chamber musician: own instrument/ neighbors > 100 dBA at fortissimo
  - Monitoring needs

Bamboozle Road Show, June 2010

- Stage Levels 94 – 108 dBA (drum kit)
- Audience 90 – 117 dBA

Sound Exposures: Bamboozle Road Show

Leq* (dBA)	105
Time (hrs)	4
Noise dose**	5000%

101.9 dBA L_{A8hn}

Table 1. Total audience exposure

Leq* (dBA)	99
Time (hrs)	7
Noise dose**	2198%

98.4 dBA L_{A8hn}

Table 2. Total crew exposure (4 hours show + sound check and setup)

* Leq is the typical 5-minute equivalent continuous sound level in A-weighted decibels

** DRC for determining "Noise dose" = 85 dBA for 8-hr Leq, 3dB exchange rate

Audiology Today MayJune 2011: pp 30-40

Damage Risk Criteria: Excess risk for "Material Hearing Impairment"

OSHA (1981): **Minimum Standard for Safety**

Organization	TWA Noise Exposure	Estimated % at Risk
ISO	*90 dBA*	*21%*
	85 dBA	*10%*
	80 dBA	*0%*
EPA	*90 dBA*	*22%*
	85 dBA	*12%*
	80 dBA	*5%*
NIOSH	*90 dBA*	*29%*
	85 dBA	*15%*
	80 dBA	*3%*
Prince, et al 1997	85 dBA	8%

Damage Risk Criteria

- OSHA
  - 90 dBA
  - 5 dB

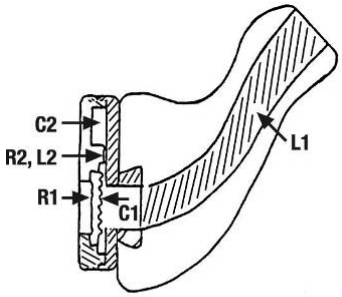
  Exchange rate
  - 90 dBA | 8 hrs
  - 95 dBA | 4 hrs
  - 100 dBA | 2 hrs
  - 105 dBA | 1 hr
- NIOSH
  - 85 dBA
  - 3 dB

  Exchange rate
  - 85 dBA | 8 hrs
  - 88 dBA | 4 hrs
  - 91 dBA | 2 hrs
  - 94 dBA | 1 hr
- WHO
  - 75 dBA
  - 3 dB

  Exchange rate
  - 75 dBA | 8 hrs
  - 78 dBA | 4 hrs
  - 81 dBA | 2 hrs
  - 83 dBA | 1 hr

LIBERAL ⇢ CONSERVATIVE

Can't we just stick a plug in it?



Schematic side view of the ER-15

C = compliance
L = inductance
R = resistance

Musicians Earplugs™ schematic design.
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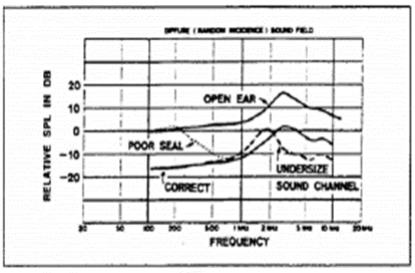


Figure 8. Expected eardrum SPL with ear open and with three constructions of ER-15 earmold.

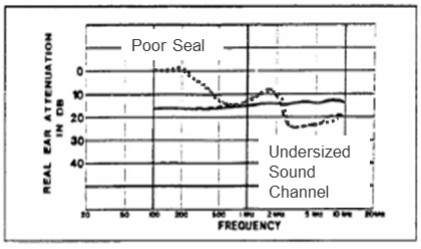


Figure 9. Calculated ER-15 performance vs. earmold construction: (—) correct (3.5 mm) sound channel, well-sealed; (. . .) poor seal, equivalent to 0.028" vent hole; (- - -) undersized sound channel (2-mm dia.).

Killion, DeVilbiss and Stewart 1988

Hypothetical Protected Sound Exposures: Bamboozle Road Show 2010

Leq (dBA)	105
Time (hrs)	4
Noise dose*	5000%
w/ ER9 (-9dB)	629%
w/ ER15 (-15dB)	158%
w/ ER25 (-25dB)	16%
w/ foam (-20dB)	50%

Only valid if plug is used > 95% of exposure time

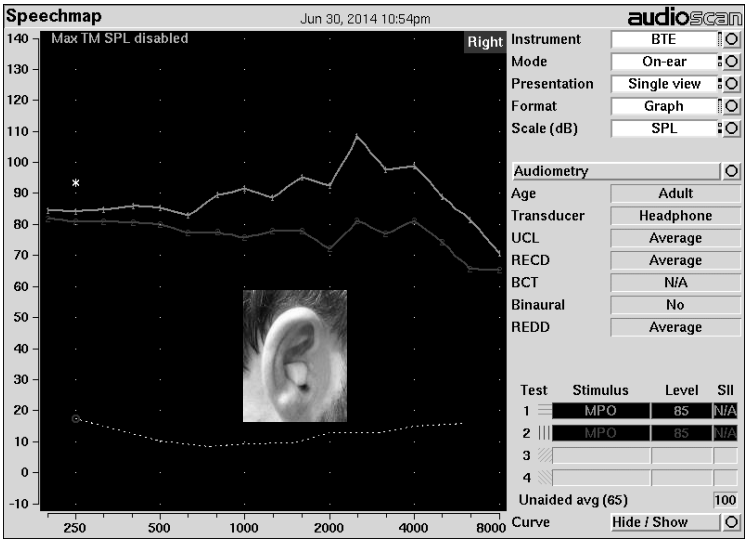
Table 3. Total audience exposure with hypothetical reduction in exposure from use of different HPD

Leq (dBA)	99
Time (hrs)	7
Noise dose*	2198%
w/ ER9 (-9dB)	277%
w/ ER15 (-15dB)	70%
w/ ER25 (-25dB)	7%
w/ foam (-20dB)	22%

Table 4. Total crew exposure with hypothetical reduction in exposure from use of different HPD

Audiology Today MayJune 2011: pp 30-40

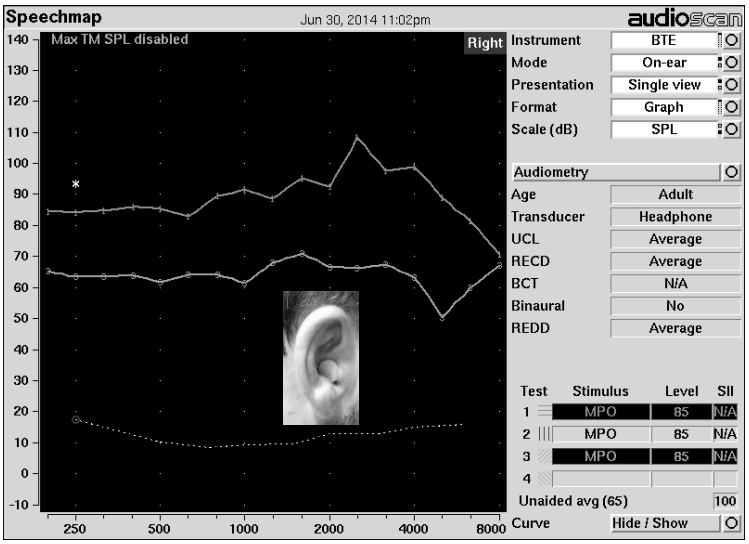
Non-Custom earplug, shallow insertion



Open

Shallow Plug

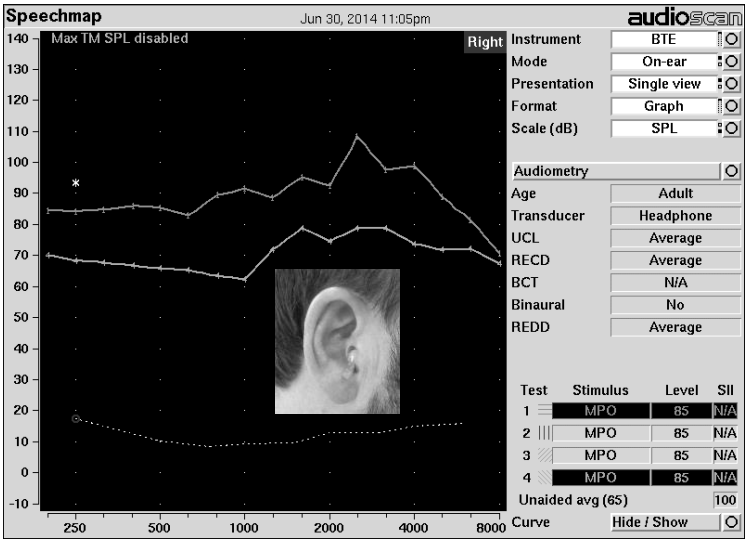
Non-Custom earplug, full insertion



Open

Deep Plug

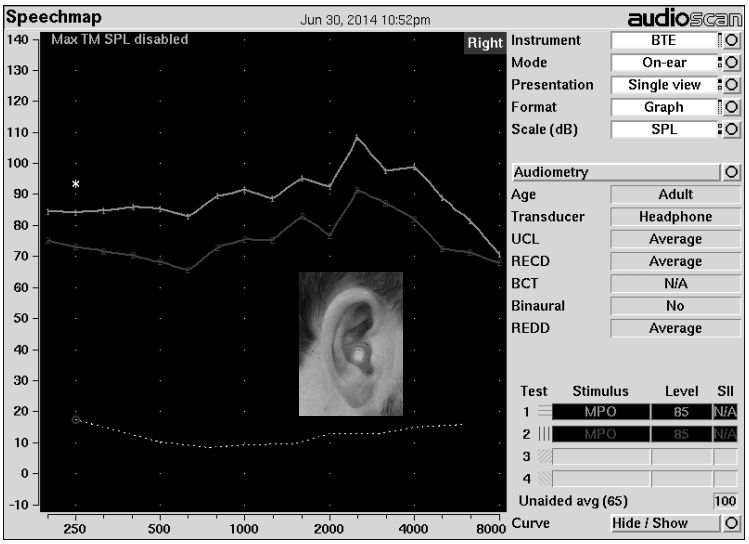
Non-Custom ER20 earplug



Open

ER20

Custom ER15 earplug



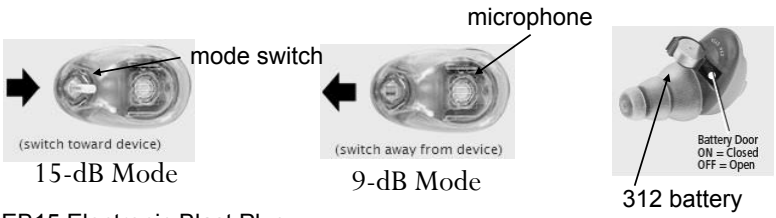
Open

ER15

Electronic earplugs

MusicPRO (Etymotic Research, Inc.)

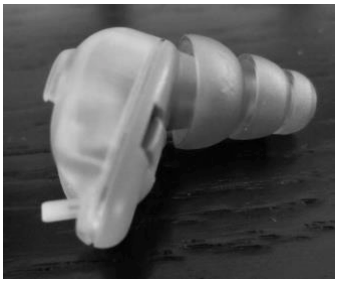
- No attenuation (unity gain) until starts compression at 70-85 dBA inputs; clips above 105/110 dB SPL
- Two modes
  - -15 dB attenuation between 85-105 dBA ("15-dB Mode")
  - +6 dB boost below 70 dBA, -9dB attenuation 90-110 dBA ("9-dB Mode)



EB15 Electronic Blast Plug
- Similar function, different range of compression and clipping

MusicPRO electronic earplugs

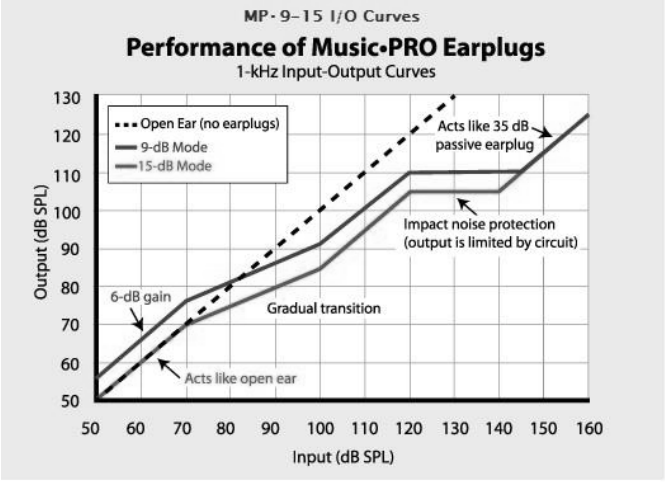
Custom Sleeve



Non-Custom Eartip

Adequate seal to combat gaps?
Piano: 27.5 – 4186 Hz
Violin: 196 – 2637 Hz

MusicPRO electronic earplugs



http://www.etymotic.com/hp/mp915.html

Custom vs. Non-Custom Earplug
Variability dictates performance, comfort

Tufts, et al. (2012):

Consistency of Attenuation, custom vs. non-custom

- Custom and non-custom: high average PAR
  - Custom: significantly more consistent 500, 1k, 2k Hz
  - Training effects: significant 250, 500, 1k Hz (both)

Tufts & Chen (2013):

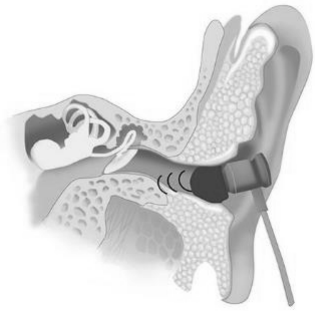
Attenuation and comfort, function of canal length (custom)

- Direct correlation: canal length and attenuation (2nd bend)
- Inverse correlation (variable): canal length and comfort
  - Lower tolerance for deviation from ideal fit deeper in canal

Consumer earphones:
Sound isolation and comfort, custom vs. non-custom

Used with permission by Sensaphonics

Non-custom earphone acoustics



Low-frequency:
Escapes gaps between earphone and canal
- Loss of bass/warmth

High-frequency:
Absorbed rather than bend around sharp curves in canal
- Loss of treble/brilliance

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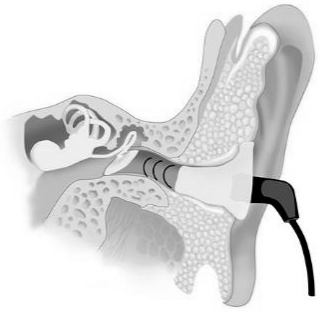
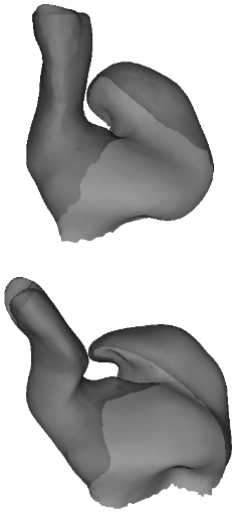
Custom earphone acoustics





Custom:
Fidelity maintained

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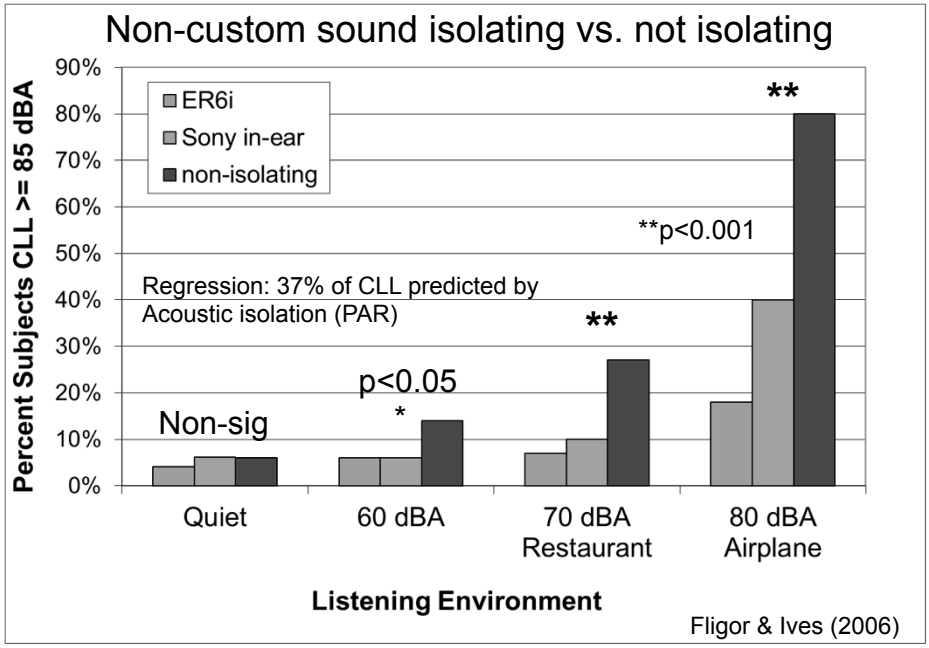
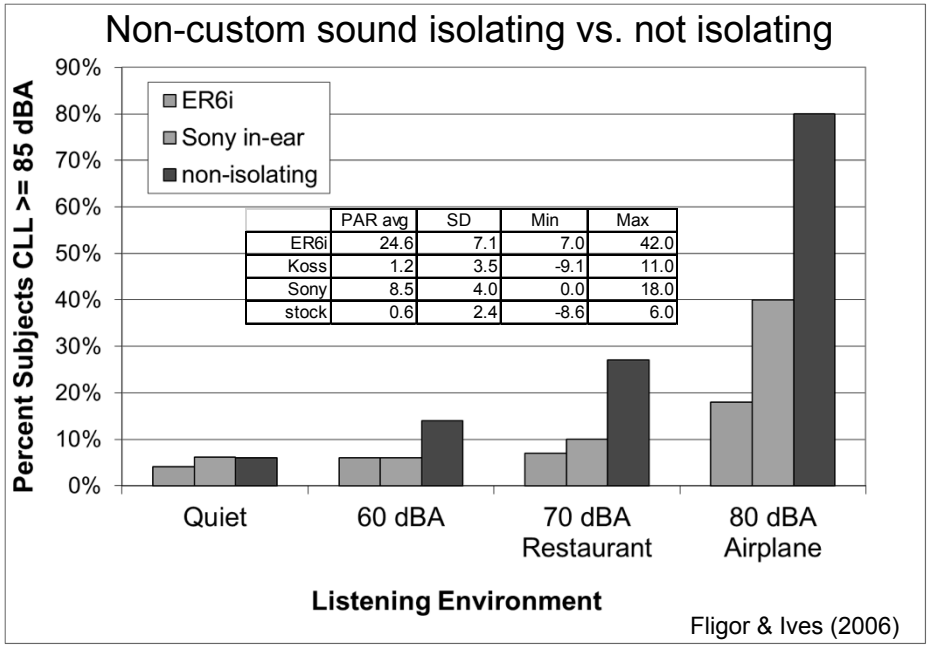

Non-custom sound isolating vs. not isolating
Percent Subjects CLL >= 85 dBA
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
ER6i
Sony in-ear
non-isolating
**
**p<0.001
Regression: 37% of CLL predicted by
Acoustic isolation (PAR)
**
p<0.05
*
Non-sig
Quiet
60 dBA
70 dBA
Restaurant
80 dBA
Airplane
Listening Environment
Fligor & Ives (2006)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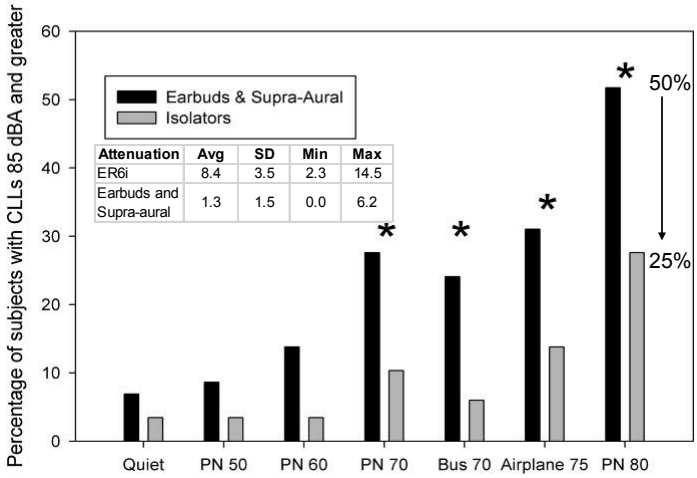
20%
10%
0%
ER6i
Sony in-ear
non-isolating
PAR avg SD Min Max
ER6i 24.6 7.1 7.0 42.0
Koss 1.2 3.5 -9.1 11.0
Sony 8.5 4.0 0.0 18.0
stock 0.6 2.4 -8.6 6.0
Quiet
60 dBA
70 dBA
Restaurant
80 dBA
Airplane
Listening Environment
Fligor & Ives (2006)

Teenagers and Earphones: Non-custom sound isolating vs. not isolating



Portnuff, Fligor & Arehart (2011)

Economics

Consumer Earphones:

- $200-450 device… $10k content download… $40 MSRP headphone (!?)
- Custom: $100 – 200 sleeves, $100 – 500 earphone

HPD:

- Disposable foam: ~20¢ per pair (2 pairs/day *21 days/month)
- Custom: $200/pair
- Cost savings after 2 years

http://www.washingtonaudiology.com/hearing-protection-cost-comparison.htm

Utility of Custom in NIHL Treatment

Coburn, et al. (2014), AAS poster

Acoustic variability of occluded earbuds in RIC hearing aid fittings

- Non-custom closed and open domes
  - Low acoustic variability in non-custom open dome fittings (direct/ambient and indirect/amplified sound; mild/mod loss)
  - High acoustic variability in non-custom closed dome fittings (extend fitting range to more severe loss)
  - Acoustic properties of coupling assumed by software

- Implications for signal processing (feedback management, gain characteristics, tinnitus masker effectiveness, battery drain)
- Increased reliability on objective verification of fitting

Summary

- ✓ Non-custom solutions are convenient in the short term, at cost of unpredictable performance
- ✓ Unpredictable performance gambles incorrect assumptions re: NIHL risk mitigation
- ✓ Customization (done well) increases likelihood of consistent HPD use
- ✓ Effective sound isolation induces PLD users to moderate listening level
- ✓ Economics can be a win-win
- ✓ Commoditization of devices, vs. customizing hearing care?