Musicians and the Prevention of Hearing Loss

Marshall Chasin, AuD.

www.MusiciansClinics.com

49th Mid-South Conference on Communicative Disorders

February 2019
Musicians’ Clinics of Canada
Rock On!

Get your earplugs

- Fitting Hearing Aids on Musicians
- Portable Music Players and Hearing Conservation
- How Outsiders Hear
www.HearingReview.com

• Feb 2009
• March 2009
• Sept 2014
• Feb 2017
• Oct 2018
A book....


• Replaces my 1996 book Musicians and the Prevention of Hearing Loss (Singular Publishing Group)
Music to your ears

• e-book from
  www.HearingHealthMatters.org
Sections on:

Hearing loss FAQs
Hearing loss prevention articles
Summary fact sheets (instruments)
Performing arts injuries
Links section
“.... Oh, just one more thing...”
The 80/90 MP3 Rule

The Fligor/Portnuff Rule (2009):

Maximum settings to obtain 50% maximum dosage...

• MP3 volume at 80% for 90 minutes

• Depends on earphone used
  • Some earphones “isolate” the ear.
  • Some earphones have different electro-acoustic characteristics.
Fligor (2006)
WHO/ITU (Feb. 2019)

• World Health Organization / International Telecommunication Union (Make Listening Safe initiative)

• Guidelines on safe(r) Smartphone use:
  • Sound allowance profile (dose)
  • Volume limiting option
  • General information.
I said, MP3 players might cause hearing loss!!

WHAT?!
Portable music is portable...

• The volume control is turned up in the presence of background noise.

• 50% volume control may be comfortable in quiet, but this same comfortable listening level may be 80% volume in noise.
Portable music is portable...

• The “best” headphone is one that isolates you from the environment...

• You won’t need to turn up the volume control in a noisy place....

• BUT, you also lose warning cues!

• BEWARE!!!
Beware of trucks coming up Behind you...
A couple of low sensitivity earphones

http://www.etymotic.com/consumer/earphones/ek5.html
Zogby International (March ’06)

• 69% would turn down the volume

• 42% would listen less often

• 36% would use special (isolator) earphones
Use earphones in both ears...

• Use the MP3 players in both ears.

• Some kids use one earphone for them and the other for their friend.

• Because of LACK of binaural summation, the volume needs to be 6 dB more intense... this is equivalent to four times the damage.
So ...

• 80/90 rule for MP3 players

• Use isolator earphones, moderation, and listen less often

• Use earphones in both ears

• BUT watch out for traffic!
How Loud?

• Noise exposure is “almost like music exposure”

• We know from factory noise exposure that 85 decibels (dBA) will eventually cause a permanent hearing loss
Some History (1968-1973)...

1973 US Environmental Protection Agency (EPA):
   Passchier-Vermeer (1968, 1971)
   Robinson (1968, 1971)
   Baughn (1973)

National Institutes for Occupational Safety and Health (NIOSH):
   Lempert and Henderson (1973)
Some History (1968-1973)...(4000Hz)

<table>
<thead>
<tr>
<th></th>
<th>Passchier-Vermeer</th>
<th>Robinson</th>
<th>Baughn</th>
<th>NIOSH</th>
<th>ISO R-1999</th>
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</thead>
<tbody>
<tr>
<td><strong>85 dBA</strong></td>
<td>8</td>
<td>6</td>
<td>9</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td><strong>90 dBA</strong></td>
<td>15</td>
<td>12</td>
<td>14</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>95 dBA</strong></td>
<td>23</td>
<td>18</td>
<td>17</td>
<td>20</td>
<td>21</td>
</tr>
</tbody>
</table>
What is 85 decibels?

• Soft Rock
What is 85 decibels?

• Telephone dial tones
What is 85 decibels?

• MP-3 player on ½ volume...
  ... but depends on earphone........
What is 85 decibels?

• Toilet flushing (with head in the bowl)

Maximum limits for symphony orchestras are achieved at anywhere between 10 and 25 hours per week of playing.
Chasin and Chong (1991)

Levels in excess of 85 dBA were measured even during a relatively quiet etude at Canada’s National Ballet with a peak level of 126 dBA.
# Maximum Levels for Instruments

*(Wagner Ring Cycle: Camp and Horstman, 1992)*

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Peak Level (dB SPL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>French Horn</td>
<td>107</td>
</tr>
<tr>
<td>Bassoon</td>
<td>102</td>
</tr>
<tr>
<td>Trombone</td>
<td>108</td>
</tr>
<tr>
<td>Tuba</td>
<td>110</td>
</tr>
<tr>
<td>Trumpet</td>
<td>111</td>
</tr>
<tr>
<td>Violin</td>
<td>109</td>
</tr>
<tr>
<td>Clarinet</td>
<td>108</td>
</tr>
<tr>
<td>Percussion</td>
<td>&gt;120</td>
</tr>
<tr>
<td>(Amplified Guitar)</td>
<td>&gt;115</td>
</tr>
<tr>
<td>Musical Instrument (at 3 meters)*</td>
<td>dB [A-weighted]</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Normal piano practice</td>
<td>60-90</td>
</tr>
<tr>
<td>Loud piano</td>
<td>70-105</td>
</tr>
<tr>
<td>Keyboards (electric)</td>
<td>60-110</td>
</tr>
<tr>
<td>Vocalist</td>
<td>70-85</td>
</tr>
<tr>
<td>Chamber music (classical)</td>
<td>70-92</td>
</tr>
<tr>
<td>Violin/viola (near left ear)</td>
<td>85-105</td>
</tr>
<tr>
<td>Violin/viola</td>
<td>80-90</td>
</tr>
<tr>
<td>Cello</td>
<td>80-104</td>
</tr>
<tr>
<td>Acoustic bass</td>
<td>70-94</td>
</tr>
<tr>
<td>Clarinet</td>
<td>68-82</td>
</tr>
<tr>
<td>Oboe</td>
<td>74-102</td>
</tr>
<tr>
<td>Saxophone</td>
<td>75-110</td>
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<tr>
<td>Flute</td>
<td>92-105</td>
</tr>
<tr>
<td>Flute (near right ear)</td>
<td>98-114</td>
</tr>
<tr>
<td>Piccolo</td>
<td>96-112</td>
</tr>
<tr>
<td>Piccolo (near right ear)</td>
<td>102-118</td>
</tr>
<tr>
<td>French Horn</td>
<td>92-104</td>
</tr>
<tr>
<td>Trombone</td>
<td>90-106</td>
</tr>
<tr>
<td>Trumpet</td>
<td>88-108</td>
</tr>
<tr>
<td>Tympani and Bass drum</td>
<td>74-94</td>
</tr>
<tr>
<td>Percussion (high hat near left ear)</td>
<td>68-94</td>
</tr>
<tr>
<td>Amplified guitar (on stage using ear-monitors)</td>
<td>100-106</td>
</tr>
<tr>
<td>Amplified guitar (on stage with wedge monitors)</td>
<td>105-112</td>
</tr>
<tr>
<td>Symphonic music</td>
<td>86-102</td>
</tr>
<tr>
<td>Amplified rock music</td>
<td>102-108</td>
</tr>
<tr>
<td>Portable music (eg, iPod) in ear canal (vol = 6)</td>
<td>94</td>
</tr>
<tr>
<td>iPod in ear canal (vol = full)</td>
<td>105</td>
</tr>
</tbody>
</table>
Guitar players on laundry day
With musicians, hearing loss is not as significant as ...

- Tinnitus
- Pitch perception problems
Two Factors Affecting Hearing Loss

1. Sound Level (in dBA)

2. Duration (hours)

....... 3 dB exchange rate
3 dB exchange rate...

- 85 dBA for 40 hours/week
- 88 dBA for 20 hours/week
- 91 dBA for 10 hours/week
- 94 dBA for 5 hours/week
- 97 dBA for 2.5 hours/week
- ...
Dosimeter
SoundLog
LAeq (dB) : 58.7

LCpk (dB) : 108.0

LAeq,8h (dB) : 42.0

Sound Exposure (Pa^2.h) < 0.001

Safe exposure time estimate > 10 hours

Last saved : 2017-02-02, 7:26 PM

[Bar graph showing LAeq by minute]

Predicted LAeq,8h (dB) : 58.7
Safe exposure time estimate: 0h 12m

Last saved: 2018-09-15, 8:40 PM

Predicted LAeq,8h (dB): 100.9
Nominal Hours: 8.0

Location at end of measurement
Longitude: -78.87849680
Latitude: 43.87469666
NIOSH Sound Level Meter
Many good SLM are only on OS and not Android

• OS (Apple) have excellent control over the software and other technologies so that app developers can be assured of good calibration.

• Android has technologies from many manufacturers and it is difficult to conclude about reliability.
...AND

• All smartphones use compressors on the input (which may be disabled... or not)

• All smartphones use directional microphones which may alter the sound level off-axis.
But...
Temporary threshold shift was equal in 4 out of 10 subjects who were exposed to noise and music of equal energy, but greater for the noise exposure in the other 6 subjects.
Hörmann et al. (1970)

Studied the emotional effects on TTS at 4kHz.

“reward” group had TTS of 12.8 dB
“punishment” group had TTS of 18.1 dB
Swanson et al. (1987)

Studied the effects of liking music on TTS

Group 1: Liked pop music
Group 2: Disliked pop music

TTS (Group 1) < TTS (Group 2)
Hating The Music

• Stress resulting in chemical changes in cochlea

Cortisol, through a glial excitotoxicity mechanism generates high levels of Glutamate throughout the cochlea and auditory system. High levels of Glutamate are ototoxic.

Opens up Calcium pathways and this influx depolarizes the cell.
Loud Noise

- Loud noise resulting in chemical changes in cochlea

Cortisol, through a glial excitotoxicity mechanism generates high levels of Glutamate throughout the cochlea and auditory system. High levels of Glutamate are ototoxic.

Opens up Calcium pathways and this influx depolarizes the cell.
FIGURE 1-4. Schematic illustrating the course of retrograde degeneration. A. Healthy ear. B. Hair cell loss leading to degeneration of the peripheral axon. C. Further degeneration involving reduced volume of the cell body. D. Demyelination of the central axon. E. Degeneration of the central axon.
Effects of cigarette smoking...


- Cigarette smoking did elevate DPOAEs in the higher frequencies even though no changes noted on conventional and high frequency pure tone audiometry.
Damage to the cochlear hair cells...

- Reactive Oxygen Species (ROS) is a metabolic by-product of cells. High noise levels can cause toxic amounts of ROS.

- Anti-oxidants may mitigate the ROS and minimize hearing loss from loud noise.

- L-NAC is an anti-oxidant.

Damage to the cochlear hair cells...

- There are a realm of “otoprotectants” that are being investigated to mitigate the effects of noise on the auditory system.
TTS protection varies with experimental agent


Some avenues being investigated...

• Oxidative Stress (eg. ROS)
  • ROS can be ototoxic

• K-recycling pathways
  • Disruption of normal $K^+$ pathways

• Heat Shock Proteins
  • Assist in intracellular transport. Higher levels can be ototoxic
Drug Trials

https://clinicaltrials.gov

Currently there are 489 trials being conducted around the world
Biochemical things and hearing loss

• Smoking and exercise:
  - availability of oxygen in the inner ear
Caffeine and noise exposure

• “Association of Caffeine and Hearing Recovery After Acoustic Overstimulation Events in a Guinea Pig Model”. Zawawi et al.

Caffeine and noise exposure

• Guinea pigs who were exposed to both caffeine and noise exposure had greater TTS as measured by ABR, and less recovery than those who were only exposed to noise.

..... Don’t visit Starbucks before going to a concert?....
Caffeine and Longevity

But.... Coffee has high levels of polyphenols- a naturally occurring anti-oxidant.
Three Factors Affecting Hearing Loss

Sound Level

Duration

“Hating the music” /stress / biochemistry
Stapedial Reflex

Zakrisson et al. (1980) studied unilateral Bell’s Palsy in humans. TTS was 10 dB greater in de-innervated ear than normally functioning ear.

Borg et al. (1983) surgically cut stapedius muscle unilaterally in rabbits. PTS was 30 dB greater in operated ear.
Stapedial Reflex and Music

Music is intermittent ... allows reflex to “reset”.

Industrial noise tends to be more steady state and reflex is only useful for first 10-15 seconds.

Maybe phonating or humming prior to a high level sound would be helpful?
Kujawa and Liberman (1997)

Increased hearing loss with ablated efferent (VII nerve)


... mentions possible “stress response”
Four Factors Affecting Hearing Loss

Sound Level

Duration

“Hating the music”/ stress / biochemistry

Stapedial reflex
Individual Factors

• Inaccurate patient noise exposure history

• Efferent neurological effects (e.g. Lonsbury-Martin, (Mecheyl et al., 1995, Perrot et al., 1999, Brashears et al., 2003)

• Differing environmentally induced bio-chemical cochlear content. (e.g. availability of oxygen (smoking, exercise))

• Genetic predisposition (e.g. Konings et al., April 2009)
## Effects of Physical Fitness at 4000 Hz

(Alessio et al., 2002)

<table>
<thead>
<tr>
<th>Age/Fitness</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teens</td>
<td>2.0</td>
<td>2.2</td>
<td>0.75</td>
</tr>
<tr>
<td>50-60</td>
<td>13.5</td>
<td>11.3</td>
<td>13.0</td>
</tr>
<tr>
<td>60-80</td>
<td>34.5</td>
<td>21.2</td>
<td>14.2</td>
</tr>
</tbody>
</table>
Alessio and Hutchinson, 2003
(2000 Hz)
Weekend warrior just as good...

• O’Donovan, G. et al. (2017)
  JAMA- Internal Medicine- two 75 minute workouts (e.g. over the weekend as in “weekend warrior”) have the same beneficial effect as working out regularly during the week (about a 30-35% reduction in mortality from all causes over an 18 year period) compared with those who do not exercise regularly, for those over 40 years old.

Five Factors Affecting Hearing Loss

• Sound Level

• Duration

• “Hating the music” / stress / biochemistry

• Stapedial reflex

• Individual factors
TTS and PTS... a caution...

• TTS = Temporary Threshold Shift
  Glutamate ototoxicity or structures of the cochlea becoming detached
  Resolves in 16-18 hours

• PTS = Permanent Threshold Shift
  Usually caused by either necrosis or apoptosis.
A: Necrosis

B: Apoptosis

Don Henderson
Should we be concerned about TTS?

• Although there are different mechanisms, some recent research suggests that permanent neural damage persists after TTS has resolved (regardless of a “normal audiogram”).

• Liberman, C., and Kujawa, S.G., 2017
• Le Prell, C.G. et al., 2012, 2018
• Stamper, G., Johnson, T., 2015.
• Bramhall, N. et al., 2017
Kujawa and Liberman, 2009

**DPOAEs**

- **a**
  - Control
  - 1 day
  - 3 day
  - 8 wk

**ABRs**

- **b**
  - Wave 1 Amplitude (μV p-p)

**Emission Amplitude (dB SPL)**

- **12 kHz**
  - 20, 40, 60, 80 dB SPL

- **32 kHz**
  - 20, 40, 60, 80 dB SPL

**Level (dB SPL)**

- **12 kHz**
  - 10, 30, 50, 70, 90 dB SPL

- **32 kHz**
  - 10, 30, 50, 70, 90 dB SPL
After resolution of TTS...

  • rapid inner hair cell (afferent) synaptic loss
  • rapid inner hair cell dendritic loss
  • slow spiral ganglion cell loss, and
  • persistent reductions in suprathreshold neural responses (i.e., reduced wave I ABR).

..... Cochlear Synaptopathy
Hidden hearing loss
Salvi et al. (2017)

Inner Hair Cell Loss Disrupts Hearing and Cochlear Function Leading to Sensory Deprivation and Enhanced Central Auditory Gain

doi: 10.3389/fnins.2016.00621
Frontiers in Neuroscience,
January 2017|Volume10|Article621
Bin Yang et al. (2018)

- Reduction of sound-evoked midbrain responses observed by functional magnetic resonance imaging following acute acoustic noise exposure

The Journal of the Acoustical Society of America 143, 2184 (2018); doi: 10.1121/1.5030920
Ridley, C. et al. (2018)

“Using Thresholds in Noise to Identify Hidden Hearing Loss in Humans”

Ear and Hearing


doi: 10.1097/AUD.00000000000000543
## Action Potentials and Summating Potentials

<table>
<thead>
<tr>
<th></th>
<th>Normal Hearing Function</th>
<th>Hidden Hearing Loss</th>
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</thead>
<tbody>
<tr>
<td>SP</td>
<td>normal</td>
<td>High</td>
</tr>
<tr>
<td>AP</td>
<td>normal</td>
<td>Low</td>
</tr>
<tr>
<td>SP/AP ratio</td>
<td>normal</td>
<td>High</td>
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</table>
Wave I and Wave V Amplitudes

<table>
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<th></th>
<th>Normal Hearing Function</th>
<th>Hidden Hearing Loss</th>
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<td>Wave I amplitude</td>
<td>normal</td>
<td>Low</td>
</tr>
<tr>
<td>Wave V amplitude</td>
<td>normal</td>
<td>High</td>
</tr>
<tr>
<td>Wave I/Wave V ratio</td>
<td>normal</td>
<td>Low</td>
</tr>
</tbody>
</table>

Can we use animal models for humans?

• Viana et al. (2015)
  • In 5 temporal bones found neural degeneration despite intact sensory cells at time of death

• Makary et al. (2011)
  • In 100 temporal bones found neural degeneration despite intact sensory cells at time of death
Cochlear Synaptopathy

• We have no reliable test measures (Wave I amplitude, SP/AP ratio, Frequency Following Response (FFR) to AM tones,...) with humans.

• We currently have no prevalence estimates with humans.

• Not sure what to do about it in any event other than to take measures and complaints of TTS more seriously.
Temporary Hearing Loss Test app

Hearing Test

- Make sure to wear headphones.
- Set your phones volume to maximum prior to each test.
- Press Measure Hearing to start the test.
- Touch and drag the dark circle to lower the volume until the tone is no longer audible.
- To store your measurement, press Save.

TTS App

You have a measurement from 0 minutes ago.
Follow up with another test to get your result.

Start New Test

Settings

Help
Temporary Hearing loss test app

Result

Measurement Interval: 0 minutes

0.44 dB

[19] There is no measureable temporary hearing loss (less than 6 dB) and it’s OK to go out and mow your lawn.

Like any test, these only provide rough estimates of the effects on your hearing. An Audiologist should be consulted for more detailed information and testing.

More information can be found at www.musiciansclinics.com/hearing_loss.asp
Temporary Hearing loss test app

[17] There is a mild amount of temporary hearing loss (between 6-15 dB) and it's important for you to stay away from noise and loud music for a day or two. Consider wearing hearing protection the next time you are in a similar environment.

Like any test, these only provide rough estimates of the effects on your hearing. An Audiologist should be consulted for more detailed information and testing.

More information can be found at www.musiciansclinics.com/hearing_loss.asp

[18] There is a significant amount of temporary hearing loss (greater than 15 dB) and it's important for you to stay away from noise and loud music for a day or two. Consider wearing hearing protection the time you are in a similar environment. Also, it would be wise to schedule an appointment with your audiologist.

Like any test, these only provide rough estimates of the effects on your hearing. An Audiologist should be consulted for more detailed information and testing.

More information can be found at www.musiciansclinics.com/hearing_loss.asp
... Musicians are “slightly” less prone to hearing loss than workers ...

Limited duration each week

Workers hate the noise

Stapedial reflex

Intermittent nature of the music
Rockers less prone to hearing loss!!!

Axelsson and Lindgren, 1981:

With age matched musicians...

13% of Rockers had a hearing loss
versus 43% of Classical musicians had a hearing loss
Rockers less prone to hearing loss!!!

Hart et al. (1987) 30% of rockers had hearing loss. vs.

Royster et al. (1991) 52% for classical music.

1. Rockers only are subjected to loud music for several hours per week.
2. Classical musicians hate their music?
3. Stapedial reflex (sings along?)
How I Assess a Musician

* Routine audiometry (pure tones, speech testing and admittance).

* If asymmetries, then ABR/MRI
  - explained (e.g. Violins, drummers)
  - unexplained (e.g. unrecalled acoustic traumas, neuromas)

* Otoacoustic emission testing

* Real Ear Measurement of their instrument
“Typical” noise induced audiogram
3000 Hz notch and 2000 Hz REUR
Audiometric Asymmetries

• Industrial exposure is (usually) symmetrical
  • Highly reverberant locations
  • Predominantly low-frequency noise

• Music exposure can be asymmetrical
  • Low reverberant locations
  • Significant mid- and high-frequency music energy
    • Head and body shadow effects
Left ear (blue) and right ear (red)
Audiometric Asymmetries

• Violinists experience a 4.6 dB greater exposure in their left ear versus their right ear.

Otoacoustic Emissions
(Drummer - symmetrical “hearing”)

Disortion Product OAEs for Mr. WJ.
Otoacoustic Emissions
(Lead singer moved away from drummer)
Otoacoustic emissions

OAE “notch” at 5000 Hz and not measured on audiometry...
So,.... Don’t smoke, and use OAEs
Real Ear Measurement

REM is modified to assess “external” stimuli

Disable the reference microphone and disable the speaker

  e.g. Audioscan:  “stimulus level = 0 dB”
  Frye:            “stimulus off”

Perform a sweep with a low-frequency, a mid-frequency, and a high-frequency sound at quiet, medium, and loud levels.
Fig. 1. Spectrum of violin playing A4 (440 Hz) without (top) and with (shaded) the ER-15 earplug. (Reprinted with permission from Chasin and Chong)
What to do with the information?

The REM data will provide information on the relative contribution of noise exposure from that instrument.

Draw a picture of the noise environment, to see who else can be the culprit (e.g. Drummer to the rear?)
Clarinet mezzo-forte vs. forte

Peak = 91 dB SPL

SPEECH INDEX:

UNAIDED

AIDED 1 0
AIDED 2 0
AIDED 3 0

SPL MODE RIGHT
Clarinet mezzo-forte vs. forte
Using Audiology to Extend a Musician's Career
Practical tips and tricks for musicians with hearing loss

Rebuilding My Musical Self 26
Patients with Normal Thresholds—and Hearing Problems 38
Preserving the Temporal Envelope 40
THIS GUY IS AN IDIOT

HE'S NOT EVEN WEARING HEARING PROTECTION
Prior to 1988...
Hearing Protection Alternatives

(after 1988)

ER-15: (1988+, Etymotic Research)

Custom made uniform attenuator provides 15 dB of attenuation up to 8000 Hz. It uses an element that interacts with an inductance to provide a 3000 Hz resonance, thus off-setting the loss of the ear canal resonance.

ER-25: (1992+)

Custom made uniform attenuator provides 25 dB of attenuation up to 6000 Hz.
Hearing Protection Alternatives

ER-9:
  Custom made uniform attenuator provides 9 dB of attenuation.

ETY plugs / ER20 XS
  Non-custom earplug with a slight high-frequency roll-off. Costs about $10-$12. (Also, Baby Blues, ER-20, and HI-FI)
Other Hearing Protection Alternatives

• Other alternatives exist:
  
  • Bilsom “Natural Sound Technology” (NST)
  
  • Dynamic Ear Company DM white filter
  
  • (Digital) signal processing approaches
  
  • Other vented/tuned approaches
    • Variable venting schemes
    • Variable (acoustic) filtering schemes
Dynamic Ear Company

![Graph showing frequency response of Filtør DM Series with lines for Filtør DM White and Filtør DM Blue. The graph includes frequency levels at 10 dB, 15 dB, 20 dB, and 25 dB.]
Fig. 1. Spectrum of violin playing A4 (440 Hz) without (top) and with (shaded) the ER-15 earplug. (Reprinted with permission from Chasin and Chong)
# Earplugs and Auditory Danger

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Danger</th>
<th>Earplug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violin/Viola</td>
<td>Violin/Viola</td>
<td>ER-15</td>
</tr>
<tr>
<td>Woodwinds</td>
<td>Percussion</td>
<td>ER-15/vented-tuned</td>
</tr>
<tr>
<td>Brass</td>
<td>Brass/Percussion</td>
<td>ER-15</td>
</tr>
<tr>
<td>Percussion</td>
<td>Percussion</td>
<td>ER-25</td>
</tr>
<tr>
<td>Amplified Instruments</td>
<td>Loudspeakers/Drums</td>
<td>ER-15</td>
</tr>
</tbody>
</table>
Fifty random ER-15 fittings
Berger (1989) based on 16 subjects
Verifying Attenuation

• Real Ear Measurement
  • REUR - REOR (“unaided” – “aided”)
  • Perform at 70 dB or greater

• Functional attenuation
  • Threshold with hearing protector in place – “unaided”
  • 2 dB steps (standard error = 2.8 dB)

• Covering the “opening” of the hearing protector subjective
14 Year Follow-up for ER-Earplugs

Survey of 850 earplug recommendations:

1990: 32% decided to get them
1995: 64% decided to get them
1997: 72% decided to get them
2005: 94% decided to get them
Follow-up for ER-Earplugs

Survey of 425 users:

83% still wearing them

14% changed to a different type (usually less)

3% did not like them (usually French Horn players)
The wrong hearing protection can be worse than none at all...

A 25 year old drummer read that he needed to use earplugs.

He started using industrial strength earplugs and 6 months later noted wrist and arm problems.
The wrong hearing protection can be worse than none at all...

<table>
<thead>
<tr>
<th>Protection</th>
<th>SPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>No hearing protection</td>
<td>103 dB SPL</td>
</tr>
<tr>
<td>“Industrial” protection</td>
<td>113 dB SPL</td>
</tr>
<tr>
<td>ER-25 (proper protection)</td>
<td>104 dB SPL</td>
</tr>
</tbody>
</table>
The wrong hearing protection can be worse than none at all...

With the ER-25, wrist and arm strain was reduced

EMG activity returned to normal

Improved monitoring was the key
Acoustic Monitor

Useful for bass string instruments such as the cello and acoustic bass.

Four feet of #13 hearing aid tubing with an adaptor. One end plugs into the left Vented/tuned earplug and the other is inserted in the “f”-hole of the cello or bass.

Similar to an acoustic stethoscope (only less than $5 in parts!)
Acoustic Monitor

![Graph showing frequency in Hz on the x-axis and relative dB on the y-axis, with a downward trend line starting at a relative dB of 20 at 500 Hz and reaching 0 at 2500 Hz.]
Bass Shakers
Attenuation from Baffles

Baffles have limited usefulness unless they are within 7 inches of the ear with optimal attenuations being 15-17 dB in the higher frequencies.

(Camp and Horstman, 1992)
Attenuation from Baffles
In-Ear Monitors

These are either:

- Custom (Futuresonics, Sensaphonics, Westone, Ultimate Ears, ...)

Or

- Non-custom (ER-4, ER-6, Shure, Sennheiser ...
In-Ear Monitors

• Federman and Ricketts (2008), JSLHR.

• With ear monitors, the Preferred Listening Level (PLL) was not lower than with stage “wedge” monitors, but the Minimal Acceptable Listening Level (MALL) was 6 dB lower than with wedge monitors.

... safe levels can be achieved,
BUT WITH COUNSELLING ...
In-Ear Monitors (in situ)
In-Ear Monitors (transceiver)

• Transceivers (some examples):
  • Sennheiser
  • Shure
Sound Level vs. Loudness

• Our role as hearing health care professionals is to “delude” the musician into thinking that the music is sufficiently loud, but at a lower sound level.
The Zen Of Hearing Loss Prevention

“Maintenance of loudness with reduction of sound level”
The Mantra....

Improved monitoring

* Bass increase
  - Shakers (ultra-low frequency woofers)

* In-ear monitors

* Acoustic monitors
So far... The Big Four ...

• Moderation

• Humming

• Improved monitoring

• Reduce environmental noise
...and the fifth one is...
Four Environmental Techniques to Reduce Noise/Music Exposure
1. Speaker/amplifier combinations should be elevated from the floor.
Energy Loss with Loudspeaker in Contact with Floor

Graph showing relative dB against frequency (Hz)
2. Strings should always have at least two meters of unobstructed space above them.
High Frequency Loss with a Poorly Constructed Pit Overhang
3. Two meters of unobstructed floor space in front of the orchestra.
Two Meters of Unobstructed Floor Space in Front of Orchestra
4. Treble brass instruments should be on risers.
Loss of energy for higher frequencies if played off of the playing plane
Why do you instantly dislike trumpet players?
Because it saves time...