AUDITORY DEMONSTRATIONS IN ACOUSTICS AND HEARING CONSERVATION

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INTRODUCTION

The most significant obstacle that must be overcome in a hearing conservation program is indifference about possible future hearing loss. People generally are not aware of, nor can they readily imagine, the long-term cumulative effects of hearing loss. Even when presented with technical information such as charts, graphs, or even electron micrographs of devastated auditory hair cells, the message may not have the desired impact. The problem appears to be that the concept of hearing loss is too abstract for many.

The primary goal of hearing conservation training must therefore be to instill the motivation to immediately and consistently take positive action to protect one's hearing. The key to developing this motivation lies in making hearing loss a less abstract concept, which can be effectively accomplished by presenting everyday sounds filtered to simulate progressive degrees of hearing loss. Experience has also shown that technical concepts such as frequency, sound pressure level and A-weighting are more readily grasped when presented in the form of auditory demonstrations.

BACKGROUND

At NASA Lewis Research Center (LeRC), 1100 civil servant and contractor employees are enrolled in the hearing conservation program. The task of hearing conservation training is made more challenging by both the wide variety of noise sources present within the more than 100 separate research facilities that comprise LeRC and the large range of educational backgrounds of the individuals enrolled in the program. To increase the impact of hearing conservation classroom training at LeRC, it was desired to incorporate effective auditory demonstrations.

Hoover & Keith Inc., through its "Noise Control for Buildings and Manufacturing Plants" Lecture Series, encounters a similar challenge with regard to providing noise control training to persons with a variety of skill sets and training levels. Demonstrations of fundamental acoustical concepts by Miller [1] and of progressive hearing loss by Glorig [2] figure prominently into the Lecture Series. These demonstrations have consistently turned out to be the most effective tool for helping students understand acoustical concepts.

Glorig's approach is to electronically filter speech and music as they would be affected by hearing loss, thus permitting nominally normal-hearing individuals to temporarily experience a simulated hearing impairment. A more recent videotape presentation using the same approach has been produced by Liberty Mutual Insurance Co. [3]. This approach to simulating hearing loss consistently results in a dramatic impact on the listener.

The demonstration series by Miller allows the audience to hear and explore acoustical concepts and their psychoacoustical analogues: pitch vs. frequency, energy vs. loudness, the harmonic series of a complex tone, octave-band filtering and A-weighted filtering.

PROJECT GOALS

It was desired to incorporate Glorig's and Miller's approaches into an expanded set of demonstrations which would serve not only the needs of the hearing conservation program but would also, with minor adaptations, provide a resource for educational outreach. To add relevance for the LeRC audience, sound samples presented at calibrated levels and drawn from sources within LeRC were preferred.

The ideal format would support a stand-alone or custom-tailored presentation for either hearing conservation training or educational outreach. Explanatory text would be added, written with elementary and secondary school audiences in mind, interleaved between the auditory demonstrations. Each auditory demonstration and associated explanatory text would then occupy a separate CD track, allowing the presentation to be tailored to the sophistication of the audience and the experience of the presenter.

Existing auditory demonstration materials did not meet all of the project goals. Glorig's and Miller's presentations are technically excellent, but with time they have come to suffer from problems of inadequate dynamic range, distortion, print-through, signal compression and added noise arising from multi-generational reproductions, and simple deterioration with age. In addition, their monaural format results in a lack of envelopment that seems to place a distance between the listener and the effects portrayed. In order to meet project goals, full advantage would have to be taken of current audio technology.

The existing materials also suffered from one or more of the following shortcomings:

- an audio tape format that makes it tedious to deviate from the recorded presentation order,
- a "stand-alone" presentation structure that is not designed to be interrupted or augmented by a lecturer, or
- insufficient focus on the topics of hearing conservation and noise control.

From a lecturer's standpoint, the practical usefulness of auditory demonstrations depends on the ease of selecting and quickly accessing individual demonstrations in order to integrate them successfully into a larger presentation. Clearly, the audio CD format permits the greatest flexibility through direct access to individual tracks.

An audio disc sponsored by the Acoustical Society of America [4] includes both desirable elements of audio quality and individual track access, but focuses mainly on complex psychoacoustic phenomena rather than hearing conservation and noise control.

At the request of NASA Lewis Research Center, Hoover & Keith Inc. has prepared an Audio Disc entitled "Auditory Demonstrations of Fundamental Concepts in Acoustics and Hearing Conservation" with the desired characteristics. The contents and a short description of the relevant technical factors for each demonstration are listed below. The Disc has been configured so that playing Tracks 4 through 46 without interruption creates a unified lecture on the subject of acoustics and hearing conservation (approximate duration: 45 minutes).

CONTENTS OF DISC

FREQUENCY

Low-pitched musical sounds	(kick drum, bass clarinet and electric bass)
High-pitched musical sounds	(ride cymbal, trumpet and clarinet)
Pure Tone: Middle C	(sinusoid: 70 dB(A))
Complex sounds: Middle C	(triangle, square, and sawtooth waveforms: 70 dB(A))
Six Harmonics of Middle C	(piano)
Music in octave bands	(63 Hz to 8 kHz)
Industrial blower, octave bands	(63 Hz to 8 kHz)
Water knife, octave bands	(63 Hz to 8 kHz)
Supercomputer, octave bands	(63 Hz to 8 kHz)

Broadband vs. tonal sound:

Jet aircraft takeoff and landing
Industrial sounds from NASA LeRC

LOUDNESS

1 kHz tone	(10 dB steps: 45 dB to 85 dB)
Broadband noise	(10 dB(A) steps: 45 dB(A) to 85 dB(A))

Hearing sensitivity vs. frequency	(20 – 20 kHz sweep, followed by a 100 Hz tone, then a 1000 Hz tone: 15 dB(A) steps, 85 dB(A) to 55 dB(A))

A-WEIGHTING

Jet aircraft takeoff and landing	(A-weighted, unweighted)
Industrial sounds	(A-weighted, unweighted)
Levels of typical sounds	(Insects: 50 dB(A), Automobile Interior: 60 dB(A), Restaurant: 70 dB(A), Vacuum Cleaner: 80 dB(A), Lawnmower: 85 dB(A))

HEARING CONSERVATION

Audiometric tones	(60 dB)
Progressive conductive hearing loss	(speech: -10 dB, -20 dB, -30 dB)
Progressive sensori-neural hearing loss	(speech: 4 kHz notch, 2 kHz lowpass, 1 kHz lowpass, 500 Hz lowpass)
Progressive sensori-neural hearing loss	(music: 4 kHz notch, 2 kHz lowpass, 1 kHz lowpass, 500 Hz lowpass, 250 Hz lowpass)
Hearing protector fitting	(pink noise: 50 Hz - 20 kHz, 3 min.)

SOUND OF NASA LEWIS RESEARCH CENTER (17 samples, 12 min.)

CONCLUSION

The Audio Disc "Auditory Demonstrations of Fundamental Concepts in Acoustics and Hearing Conservation" provides a flexible series of auditory demonstrations that are digitally recorded and mastered and, wherever possible, incorporate sounds from NASA Lewis Research Center. By creative planning and forethought, it has been made flexible enough to serve as either a stand-alone presentation or as support material for an experienced presenter. In addition, it has been configured to address both the technical needs of NASA Lewis Research Center's hearing conservation program and a dual-use function as a resource for educational outreach.

REFERENCES

[1] Laymon N. Miller, Noise Control Lecture Series, 1969-1996
[2] Dr. Aram Glorig, American Academy of Opthamology and Otolaryngology
[3] "*What Hearing Loss Sounds Like",* Liberty Mutual Insurance Company
[4] A. J. M. Houtsma, T. D. Rossing, W. M. Wagenaars, *Auditory Demonstrations*, (Acoustical Society of America, 1987)