Baltimore, Maryland
NOISE-CON 2004
2004 July 12 - 14

Auditory Demonstrations II: Challenges to Speech Communication and Music Listening

Beth A. Cooper
NASA John H. Glenn Research Center at Lewis Field
21000 Brookpark Road M.S. 86-10
Cleveland, Ohio 44135 USA

David A. Nelson
Nelson Acoustical Engineering, Inc.
P.O. Box 879
Elgin, Texas 78621 USA

Richard W. Danielson
National Space Biomedical Research Institute and Baylor College of Medicine
NASA Johnson Space Center
2101 NASA Road 1 SD32
Houston, Texas 77058 USA

1. INTRODUCTION

The NASA Glenn Research Center Acoustical Testing Laboratory has produced a compact disc with a collection of auditory demonstrations that illustrate the impact of acoustical conditions and hearing loss on everyday listening situations. These demonstrations illustrate both the need for, and the benefits of, noise control efforts in a wide range of situations where good speech intelligibility is desirable. Copies of the disc will be distributed to the attendees at this NOISE-CON presentation. (Single copies of the demonstration disc are available free by completing the on-line request form at the NASA Glenn Research Center Acoustical Testing Laboratory web site at http://acousticaltest.grc.nasa.gov.)

Although *Auditory Demonstrations II* was developed primarily as a vehicle to further low-noise advocacy within NASA's space flight (and ground-support) programs, it was designed to have broad applicability in the larger technical community. For example, engineers, architects, policymakers, and health care professionals could use these demonstrations to experience and tangibly gauge the true cost of communication interference due to noise and hearing loss. In addition to the thirty-four tracks of communication demonstrations in this collection, the disc includes recordings of several styles of music that have been modified to demonstrate auditory changes due to progressive noise-related hearing loss.

This presentation will discuss potential applications and desired outcomes of these demonstrations in support of noise control and hearing loss prevention initiatives. Approaches for effectively using one or more of the demonstrations will be demonstrated in the context of various advocacy efforts. The authors will distribute (and continue to provide on request) a set of briefing slides that may be used to accompany selected demonstrations.

2. DESCRIPTION OF SPEECH COMMUNICATION DEMONSTRATIONS

Noise affects our lives in many different situations. At high sound levels, ongoing exposure can lead to noise-induced hearing loss. Even at low levels, some sounds can cause annoyance or distraction. Within this continuum lies a vast range of experiences that encompass most of our daily lives including workplaces, vehicles, restaurants, etc., where the chief noise complaint is usually difficulty in understanding speech. The difficulty only increases when the environment is highly reverberant and/or the listener has hearing loss.

It is more difficult to motivate noise control efforts for the sake of speech intelligibility than for hearing conservation because it is generally perceived that noise interference with speech is merely an "inconvenience." Furthermore, it is thought to be easy to adopt a variety of coping mechanisms such as speaking up and moving nearer to the speaker. However, these mechanisms may not be practical or sustainable in many communication situations.

The demonstrations on this disc are intended to cast the listener as a third-party listener in situation-appropriate conversations in the following arbitrarily-chosen environments:

A. Spacecraft interiors
B. Automobile passenger compartments
C. Aircraft passenger cabins
D. Meeting rooms
E. Restaurants
F. Industrial facilities
G. Classrooms

In the demonstrations, the listener is virtually placed in the middle of challenging real-life situations without the benefit of usual coping mechanisms. The speakers do not raise or lower their voices, nor do they move relative to the listener. As a result, the inability to adapt to the situation dramatically highlights the need for noise control.

3. PRODUCTION OF THE DEMONSTRATIONS

While these demonstrations might appear to be artificial or restricted to a given listening situation, the demonstrations have been carefully constructed to represent appropriate sound levels from participants in actual conversations, with corresponding acoustical conditions. The scripts are intended to be compelling and entertaining, so that loss of speech intelligibility can be expected to create a sense of frustration.

Ambient sounds native to a number of environments are presented at appropriate levels. They are presented singly or in sequence, usually from best to worst speech intelligibility. For some tracks, broadband noise has been synthesized to match Noise Criterion (NC) curves (see Table 1). In others, sounds intruding into the listening space are filtered to simulate performance of various partitions ranging from Sound Transmission Class (STC) 20 to 60 (see Table 2).[1]

On most tracks, the listener is assumed to have no hearing loss. Some tracks are filtered so that a normal-hearing person can experience hearing loss that might be predicted (based on ISO 1999 – see Table 3) for exposure to 90 dBA (unprotected, or at the ear) for 8 hours per day over a period of years.[2]

Other tracks are filtered to simulate use of hearing protectors with rated attenuation ranging from Noise Reduction Rating (NRR) 12 to 29 (see Table 4).[3]

Finally, on some tracks digital reverberation has been added to increase realism and to demonstrate the effects of reverberation on speech intelligibility.

4. DESCRIPTION OF MUSIC LISTENING DEMONSTRATIONS

A demonstration of music listening with progressive sensorineural hearing loss was included on this CD's predecessor disc, *Auditory Demonstrations in Acoustics and Hearing Conservation*. [4] (Single copies of that disc are available by completing the online request form at http://acousticaltest.grc.nasa.gov.) The original demonstrations used a passage of classical music, repeated with successive "brick-wall" low pass filters. Each of the updated presentations on this CD uses a single passage of music, drawn from one of many popular styles, which has been sequentially filtered to more accurately reflect hearing loss characteristics drawn from ISO 1999. The filters are generated with median hearing loss (HL) values (which include hearing loss due to aging) for an unscreened population exposed for 8 hours per day to 90 dBA (unprotected, or at the ear) for 0, 5, 10 . . . 40 years. Musical selections are filtered to simulate 5-year exposure increments, with each 5-year increment indicated by a "beep." The music is still audible and for the most part intelligible, although certainly far less enjoyable. The filter reverts to the acoustic characteristics of the "0 year case" at the end of each presentation. This sudden change (back to unfiltered modes, representing undamaged, young ears) often generates at least some degree of astonishment among listeners in the audience, who have become accustomed to the gradual filtering.

Music listening demonstrations include the following styles of music: Pop, Rap, Rock, Country, Latin, Techno, Jazz, Classical, Big Band, and Swing.

5. HOW TO USE THE DEMONSTRATIONS

The demonstrations may be used in the context of advocacy and educational presentations to illustrate the effects of various challenges to speech communication. The challenges may be presented singly or in combination and are often most effective when presented as a series of progressive steps, demonstrating a single challenge before combining it with another. The challenges represented in the demonstrations are listed below and cross referenced by track number in Table 5. Detailed track descriptions are included in the liner notes booklet packaged with the demonstration disc.

A. Sequence of Noise Criterion (NC) background sound levels, increasing and decreasing progressions
B. Sequence of "typical" environmental sounds, in order of increasing sound level
    1. Automobiles (interior sounds due to typical continuous noise sources)
    2. Restaurants
    3. Aircraft (interior passenger cabin sounds)
    4. Classrooms
        a) Outdoor environmental sounds such as traffic and aircraft
        b) Indoor environmental sounds such as HVAC noise and gymnasium sounds
    5. Industrial background sounds
C. Competing conversations and competing activities in adjacent architectural spaces
D. Architectural acoustics parameters
    1. Sequence of STC-rated wall partitions, illustrated by crosstalk from adjacent space
E. Sequence of increasing reverberation time
F. Intrusion of environmental noise from an adjacent space, external and internal
G. Effects of hearing protectors (while listening to speech)
    1. High-attenuation foam earplug
    2. "Flat" (moderate) attenuation earplug
H. Effects of progressive hearing loss on listening to speech communication
I. Effects of progressive hearing loss on listening to a variety of styles of music

6. SUMMARY

Auditory messages provide a rich and indispensable component of our daily lives. If communication is disrupted by poor acoustical conditions or by hearing loss, the lively and satisfying interactions that we take for granted can be confusing and frustrating. The National Aeronautics and Space Administration has produced this collection of auditory demonstrations to illustrate the impact of acoustical conditions and hearing loss on everyday listening situations. In addition, recordings of several styles of music have been modified, demonstrating auditory changes due to progressive noise-related hearing loss. We encourage you to employ these demonstrations in your own noise control engineering and hearing loss prevention programs.

7. REFERENCES

1. Cyril M. Harris, ed., *Noise Control in Buildings* (McGraw-Hill Inc., New York, NY, 1994)

2. *Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment*, International Standard ISO 1999–1990 (International Organization for Standardization, Geneva, Switzerland, 1990)

3. E.H. Berger, L.H. Royster, D.P. Driscoll, J.D. Royster, and M. Layne, *The Noise Manual (Fifth Edition)* (American Industrial Hygiene Association, Fairfax VA, 2000).

4. D.A. Nelson and B.A. Cooper, “Auditory Demonstrations in Acoustics and Hearing Conservation”, *Proc Noise-Con 98*, edited by J. Stuart Bolton and Luc Mongeau, pp. 45-48, (Noise Control Foundation, Poughkeepsie, NY,1998).

8. ACKNOWLEDGEMENTS

Technical sound signals for the auditory demonstrations were developed by Nelson Acoustical Engineering under contract to NASA Glenn Research Center, with communication scripts and studio engineering subcontracted to Tequila Mockingbird Studios (Austin, TX).

Table 1
Artificial Environments: NC Curves

Noise Criterion Curve	Octave Band Sound Pressure Level [dB]							
	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
NC 15	47	36	29	22	17	14	12	11
NC 20	51	40	33	26	22	19	17	16
NC 25	54	44	37	31	27	24	22	21
NC 30	57	48	41	35	31	29	28	27
NC 35	60	52	45	40	36	34	33	32
NC 40	64	56	50	45	41	39	38	37
NC 45	67	60	54	49	46	44	43	42
NC 50	71	64	58	54	51	49	48	47
NC 55	74	67	62	58	56	54	53	52
NC 60	77	71	67	63	61	59	58	57
NC 65	80	75	71	68	66	64	63	62

Table 2
Building Components, Insertion Loss

Sound Transmission Class	Octave Band Insertion Loss [dB]							
	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
STC 20	6	10	18	20	20	20	19	20
STC 25	5	12	21	25	26	26	25	26
STC 30	7	12	21	27	30	31	29	31
STC 35	11	18	26	34	36	36	36	37
STC 40	16	18	26	37	46	44	43	54
STC 45	18	23	35	44	51	48	44	56
STC 50	19	27	38	48	54	53	52	64
STC 55	18	29	45	55	57	59	57	66
STC 60	22	35	49	60	61	63	62	71

Table 3
Progressive Sensorineural Hearing Loss*

Exposure Duration	Hearing Loss [dB]					
	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz
5 Yrs	0	0	0	5	8	5
10 Yrs	1	1	3	10	13	9
15 Yrs	1	1	5	12	15	12
20 Yrs	2	2	7	14	18	15
25 Yrs	3	3	9	17	22	19
30 Yrs	4	4	12	20	25	23
35 Yrs	5	6	14	23	29	28
40 Yrs	6	7	17	27	34	34

*50th percentile, average male/female, 90 dBA exposure, 8 hours per day, per ISO 1999.

Table 4
Hearing Protectors, Attenuation Data*

Noise Reduction Rating	Octave Band Attenuation, dB								
	125	250	500	1000	2000	3150	4000	6300	8000
NRR 12	15	15	17	19	23	23	20	22	25
NRR 16	12	17	24	23	24	27	25	23	26
NRR 20	12	16	27	32	33	35	38	42	42
NRR 25	17	22	34	40	35	36	38	38	40
NRR 29	37	41	45	44	36	42	43	46	47

*http://www.aearo.com/html/products/hearing/atten01.htm

Table 5
Matrix of Demonstrations by Track Number

	Interior Ambient Noise*	**Intruding Ambient Noise**	**Hearing Loss**	**Hearing Protectors**	**Reverberation**
Spacecraft	4,5,6		7,8		
Automobile	9		10		
Restaurant	12		13		
Meeting Room	17	15,16			18
Classroom	21	20,21			21
Aircraft	23		24		
Industrial	26		26, 29-32	28-32	
Music			35-44		

*could include sequence of NC backgrounds, typical interior environmental sounds, competing conversations