Evaluating the Operational Impact of Hearing Impairment

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Operational Importance of Hearing
Police, Fire, Rescue, Military, Command and Control

Hearing is essential in many critical, high-risk activities

- **Communication:**
  - Quiet, at a distance, on a radio, in noise, when distracted

- **Detection:**
  - At a distance, in the dark, from behind, when you’re asleep
  - Enemy incursions, incoming fire, tripwires, civilian activity

- **Localization:**
  - Footsteps, gunfire, voices, warnings

- **Maintaining acoustic stealth:**
  - **Are you** making noise? (e.g., footsteps, clothing-on-clothing, equipment being carried)
Operational hearing can be impaired many ways:

- Noise-induced hearing loss or other ear disorders
- The use of hearing protection devices
- The presence of noise in the environment
However, there is very little quantitative data to tell us how much hearing impairment degrades performance.

This information is needed to make informed decisions:

- **Developing Auditory Fitness-for-Duty Standards**
  - How much NIHL can be tolerated in critical occupations?

- **Establishing HPD and Radio/Intercom Requirements**
  - How much hearing acuity must be preserved for safe operation?

- **Making informed trade-offs in noise control engineering**
  - Evaluating the cost/benefit ratio of noise abatement
What is needed?

In a very broad sense, we need to generate curves like this...

But how do we do it?
A full-factorial experiment would require:

- Trained operators performing realistic tasks with valid outcome metrics
- All possible types of hearing impairment, hearing protector, otoprotectant use
Complexity of Problem

Such a full-factorial experiment is rarely, if ever, feasible

1) Operational testing is expensive and time consuming

2) Trained operators with all levels of NIHL are not available
   - Even if they were, differences in individual skill confound results

3) Testing with all possible HPDs is cost-prohibitive
   - Also, practical considerations mean we need to be able to generalize result to future HPDs without re-running tests
Proposed Solution

In order to reduce the complexity of the problem, we propose the use of real-time hearing loss simulation systems

1) Recruit trained operators with normal hearing

2) Systematically degrade their hearing with hearing-loss simulation systems

3) Measure operational hearing as a function of simulated hearing acuity
Example 1: HLSim

The HLSim hearing loss simulator is designed to evaluate the impact of elevated detection thresholds (due to NIHL or the use of a HPD) on operational performance.
HLSim Overview

- Developed by Sensimetrics Corp
  - Technology originally developed by NSMRL and ONR to aid hearing loss prevention counseling
- Microphone on insert earphone
  - Passes through direct sound
  - Attenuation of plug + masking added noise can simulate any detection audiogram
Paintball version of “Hunger Games”

Mission Objectives:

• Move to initial positions
• Eliminate all other players
• Avoid being eliminated

4-8 players in each round

Each played with four hearing levels
• No loss
• Mild loss ($PTA_{0.5,1,2k} = 30$ dB)
• Moderate loss ($PTA_{0.5,1,2k} = 40$ dB)
• Severe loss ($PTA_{0.5,1,2k} = 90$ dB)
Hearing had modest impact on “survivability”
Preliminary Experiment at West Point
Effect of Audibility on Dismounted Combat

But severely impaired “lethality”
Preliminary Experiment at West Point
Effect of Audibility on Dismounted Combat

And overall victory was very difficult with more than a mild hearing loss
Preliminary Experiment at West Point
Effect of Audibility on Dismounted Combat

And overall victory was very difficult with more than a mild hearing loss

Although those with mild hearing loss did quite well…
Seemed to be related to adoption of very aggressive strategy in the no-loss condition
Example 2: Adaptive Intelligibility Modification System (AIMS)

The AIMS hearing loss simulator is designed to allow systematic control of speech intelligibility both in radio and face-to-face communications...

- Wireless and hands-free, to avoid interfering with operational tasks
- Fast enough to preserve audio-visual speech cues
- Adjusts level of input speech to comfortable level with 3-band AGC
  Then adjusts level of background noise to control intelligibility of speech
- This is better than simply injecting noise in environment
  - Prevents speakers from talking louder to “talk over the noise”

![Image of the AIMS system interface]
AIMS Methodology

1) Measure performance vs. SNR for trained operators wearing AIMS
2) Measure intelligibility vs. SNR for same operators using AIMS
3) Use results to plot curve of operational performance vs. intelligibility

4) Later experiments or simulations (SII, STI) can be run in the lab to determine the effects of different noise levels, different levels of hearing impairment, or different types of communication or HPD technology on intelligibility

Allows evaluation of operational impact of acoustic changes in environment without running additional tests directly with trained operators
Preliminary Results

Results show AIMS is able to reliably control intelligibility
Ongoing Research Projects

Effect of impaired communication on command and control effectiveness
Aegis Simulator
NSWC - Dahlgren, VA

Effect of impaired communication on combat effectiveness in a firefight
Engagement Skills Trainer
USMA - West Point, NY
Summary and Conclusions

Two Hearing Loss Simulation Systems have been developed to examine the operational impact of hearing impairment.

In a coordinated effort with other DoD organizations, we are conducting and planning studies using this unique approach.

These efforts have implications for the development of:

- auditory fitness-for-duty standards
  
  and

- specifications for future hearing protectors and communications equipment
Thank You!

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