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Considerations in the Evaluation of Auditory Fitness for Duty in Military Personnel

Douglas S. Brungart
Chief Scientist
National Military Audiology and Speech Pathology Center

Disclaimer

The views expressed in this talk are those of the authors and do not necessarily reflect the official policy or position of the Department of the Army, the Department of the Navy, the Department of the Air Force, the Department of Defense, nor the U.S. Government.

I have no actual or apparent conflicts to disclose
Auditory Fitness for Duty: A Review

Auditory fitness for duty (AFFD) refers to the possession of hearing abilities sufficient for safe and effective job performance.

Importance of Hearing in Operational Environments

The essential nature of hearing for military operations is undisputed
- Most agree that deaf individuals are unfit for duty
- However, little is known about “how well” warfighters need to hear

However, hearing acuity in military environments is rarely ideal
- Auditory stimuli are masked by loud weapon systems
- Situation awareness is impaired by use of Hearing Protection
- Speech signals are degraded by encryption, noise, use of PPE
- Hearing ability is impaired by hearing loss

Hard choices about hearing must be made all the time in the military
- Should an experienced soldier be disqualified due to hearing loss?
- Should a hearing protector be worn on a combat patrol?
- Should a weapon system be quieted despite loss of capability?
Components of Situation Awareness

In military environments, there are four critical components of situation awareness that may be impaired by HPDs or NIHL:

1) Detection and Identification
2) Localization
3) Communication
4) Acoustic Stealth

Evaluating Operational Impact of Hearing Impairment

Even in cases where it is possible to accurately assess hearing acuity, rational decision making is only possible if we can determine the relationship between hearing acuity and mission effectiveness.
Evaluating Operational Impact of Hearing Impairment

Even in cases where it is possible to accurately assess hearing acuity, rational decision making is only possible if we can determine the relationship between hearing acuity and mission effectiveness.

How Good is Good Enough?

Evaluating Operational Impact of Hearing Impairment

These questions can only be answered if we are able to generate curves relating operational performance to metrics of hearing acuity.

- Providing Training on Hearing Protection Devices
- Developing and selecting new HPDs
- Justifying the use of engineering noise controls
- Establishing auditory fitness-for-duty standards
Unfortunately, hearing loss is very prevalent in armed forces

- Tinnitus and Hearing Loss are the most common permanent injuries experienced by Service Members
- More than 250,000 service members have reported hearing loss following redeployment from OIF/OEF
- At the current estimated rate of increase, the number of veterans with a service-connected tinnitus disability will increase to over 1.5 million by 2014

The combination of the critical importance of hearing to military operations and the prevalence of hearing loss makes hearing one of the top readiness issues in the DoD

When faced with a military members who have acquired a hearing loss, audiologists must make critical judgments:

*Is this individual’s hearing loss severe enough to prevent the safe and effective execution of their military mission?*

*Do they need to be reassigned or separated from service?*
Identifying Mission Critical Auditory Tasks (MCATs)

Noise and Health Papers from UK

Fit for the frontline? A focus group exploration of auditory tasks carried out by infantry and combat support personnel

Zoë L. Bevis, Hannah D. Semeraro, Rachel M. van Besouw, Daniel Rowan, Ben Lineton, Adrian J. Allsopp

Fit for the frontline? Identification of mission-critical auditory tasks (MCATs) carried out by infantry and combat-support personnel

Hannah D. Semeraro, Zoë L. Bevis, Daniel Rowan, Rachel M. van Besouw, Adrian J. Allsopp
Identifying MCATS

Stage 1: Exploration of auditory tasks

Method
Focus groups
80 infantry personnel
Range of ranks
Active service experience
Qualitative analysis

Results
Seventeen auditory tasks
- Eight speech communication
- Six sound localisation
- Three sound detection

Identifying MCATS

Stage 1: Exploration of auditory tasks → Stage 2: Determination of MCATs

Hearing commands in a casualty situation
Hearing grid references
Hearing directions on patrol
Hearing directions in a vehicle
Hearing fire control orders
Hearing stop commands
Hearing the briefing before a foot patrol
Communicating through an interpreter
Locating a small arms firing point
Locating an artillery firing point
Locating the moving sound source of a motorbike
Locating the moving sound source of footsteps
Locating enemy movement in maize fields
Locating a talker
Identifying the type of weapon system being fired
Determining talker identity
Detecting a malfunction in an item of machinery
### Method:
- Questionnaire with Likert scale ratings
- 87 infantry personnel
- Quantitative analysis

### Identifying MCATS

#### Which of the 17 auditory tasks are mission critical?

<table>
<thead>
<tr>
<th>CONSEQUENCES of poor performance</th>
<th>WHO performs this task?</th>
<th>FREQUENCY of task</th>
</tr>
</thead>
<tbody>
<tr>
<td>In your opinion how significant are the consequences of poor performance on this task?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = No Consequence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = Minor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = Moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = Major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 = Critical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = No infantry personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = Some infantry personnel (indicate which roles)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = All infantry personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = Seldom or yearly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = Occasionally or monthly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = Regularly or weekly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = Frequently or daily</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 = Continuously or several times per day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Speech Communication
- T1: Accurately hearing commands in a casualty situation
- T2: Accurately hearing grid references
- T3: Accurately hearing directions on patrol
- T4: Accurately hearing directions in a vehicle
- T5: Accurately hearing fire control orders
- T6: Accurately hearing 'stop' commands
- T7: Accurately hearing the briefing before a foot patrol

#### Sound Localisation
- T9: Locating a small arms firing point

#### Sound Detection
- T15: Identifying the type of weapon system being fired
Clinical Tools to Assess Fitness for Duty

Clinical Tools to Efficiently Assess Hearing Loss

All services now require an entrance audiogram

All services require annual audiograms for those who are noise exposed

All Soldiers (Army) and Marines are now required to get annual monitoring audiograms

Hearing losses are typically detected by surveillance
Clinical Tools to Efficiently Assess Hearing Loss

Current Army Standard (AR40-501) defines a two-stage process for assessing AFFD

First stage is a Hearing Profile (H1-H3) defined by audiometric thresholds

Second stage is score on 200-word Speech Recognition in Noise Test (SPRINT)
NU-6 Words, 6-Talker Babble
+9 dB SNR, 50 dB HL
Assessment of Fitness for Duty

Once SPRINT score is determined, recommendation is based on Sprint Score and years of service

<table>
<thead>
<tr>
<th>Category</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Retention in current assignment</td>
</tr>
<tr>
<td>B</td>
<td>Retention in current assignment with restrictions</td>
</tr>
<tr>
<td>C</td>
<td>Re-assignment to or retention in non-noise hazardous AOC/MOS</td>
</tr>
<tr>
<td>D</td>
<td>Discretionary (audiologist chooses between C or E)</td>
</tr>
<tr>
<td>E</td>
<td>Separation from Service</td>
</tr>
</tbody>
</table>

Re-Evaluation of the SPRINT Test

The 200-word SPRINT is a long test

It takes 20 minutes to complete

Is there a way to increase efficiency?
Re-Evaluating the SPRINT Test

The 200-word SPRINT is a long test

It takes 20 minutes to complete

Is there a way to increase efficiency?

It turns out, there is!

Not all 200 words are equally difficult
Eight are difficult for everyone
Roughly 100 are easy for everyone

If we pick the hardest words, but exclude the bottom eight
we can almost perfectly predict 200-word result with 100 words
New 100-word SPRINT Test

New SPRINT approved for Army Use in 2013:
For DoD/VA, Available from Army Hearing Program:

Issues with current FFD standard

Current standard does not provide a link between clinical tests and performance in operational tasks

In order to establish link, we need large N study with
- Audiogram Data
- Speech-in-Noise Data from Clinical Test
- Performance in one or more operational tests

Practical approached needed to get data from 100’s of SMs

James.d.hite.civ@mail.mil
USAPHC Army Hearing Program
5158 Blackhawk Rd, Bldg E-1570
Edgewood, MD 21010-5403
Speech-in-Noise Tests for Auditory Fitness-for-Duty

Two 104-word lists of equal difficulty selected:
- Closest in overall difficulty selected from 5 possible lists

Test conducted in closed-set trial:
- 10 Practice trials
- 104 Test trials (52 with Target at 78 dBA SPL, 52 at 72 dBA SPL)
- 10 “Easy” catch trials randomly interleaved in block

MRT Spectra adjusted with linear “CAM Fit” for typical H3
Gain for thresholds
- 20 dB @ 500 Hz
- 20 dB @ 1000 Hz
- 35 dB @ 2000 Hz
- 70 dB @ 4000 Hz

Masked by speech-shaped noise matching spectrum of target speech
Speech-in-Noise Tests for Auditory Fitness-for-Duty

Modified Rhyme Test was evaluated on 469 Listeners:
- Walter Reed Audiology Clinic
- Walter Reed Hearing Conservation Clinic
- Ft. Benning Hearing Conservation Clinic

414 Listeners were <= 65 Years Old

Only 3 scored less than 90% correct on catch trials (!!!)

Left a total of 411 listeners for evaluation

Speech-in-Noise Tests for Auditory Fitness-for-Duty: MRT

Overall level has no impact on performance - even for H3
This implies that MRT measured “distortion” not “audibility”
Decision was made to piggyback on current DoD hearing conservation program
- Annual Audiogram collected from all Active Duty Soldiers and Marines
- Audiogram collected using automated system (DOERHS-HC)

FIT Test Sites

Active FIT Sites

- WRNMMC
- Ft. Campbell
- Ft. Benning
- Camp LeJeune
- Pendleton
- Ft. Stewart
Proposed FIT Sites

- San Diego
- Miramar
- Okinawa
- Quantico
- Quantico
- Pentagon
- Madigan
- Portsmouth
- Seymour Johnson
- Ft. Meade

Speech-in-Noise Tests for Auditory Fitness-for-Duty: MRT

Cumulative Probability Distribution

Proportion Correct MRT Responses
Test Operational Sounds on Hearing Impaired Listeners

First approach:

Measure real operational sounds in field...

Test on real hearing impaired listeners

Extending to Operational Hearing

Recordings have been made with custom binaural device at the Joint Readiness Training Center (JRTC), Ft. Polk, Louisiana

JRTC is the last stage of training for units deploying to Afghanistan
Extending to Operational Hearing

Quiet 73 dB
TOC 73 dB
Crowd 78 dB
Humvee 85 dB
Chopper 87 dB

Talker 0.5 m from listener (0.25 m in TOC)

Ft Polk Operational Tests

Matrix speech tests have “face validity”, but don’t reflect true environment

What about the real battlefield environment
- Complex background noises
- Highly stressed talkers

continued
In the following scenario, imagine you are receiving critical battlefield instructions from your unit commander. You will be shown a still picture with accompanying audio to depict this situation. Your objective is to listen for the key pieces of information communicated. You will then be asked one or more questions about what you heard.

Press the button below when you are READY.
Ft Polk Operational Tests

Please answer the following questions and click SUBMIT to proceed.

What is Bravo Attack told to do on the perimeter?
- Air support
- Snipers
- Vehicles
- Wounded soldiers

How many are on the perimeter?
- 2
- 3
- 4
- 5
- 6

What are they supposed to do with these?
- Load them into Zortka
- Load them into Humvees
- Load them into a tarpaulin
- Load them into a vehicle

Where are they supposed to take them?
- To the first hospital
- To the POD
- To the H2
- All of the above

SUBMIT

Ft Polk Operational Tests

FIT Protocol

In the following scenarios, you will hear communications recorded during a military training exercise. Listen carefully to what is said. Then, answer the questions that follow. Press the button below when you are READY.
Ft Polk Operational Tests

Scenario 14

Listen to Your Unit Commander
He has important information for you. Click Begin when you are ready.

Ft Polk Operational Tests

Scenario 14

What are you to do with Sgt. Porter?

- Pull him back
- Tell him to flank right
- Provide cover for him
- Put him on the other side
Pulling it All Together

Developing a validated auditory fitness standard requires testing on a large number of representative subjects...

Requires combination of
1) Pure-Tone Audiogram
2) Clinical Speech-in-Noise Test (MRT)
3) One or more operational tests

We are now developing an architecture to achieve this as part of routine DOEHS-HC audiogram

Putting it All Together

Results will be used to develop 2D "Risk Analysis" table

1) For each operational test, determine 10th percentile for unmodified signal for “normal” hearing listener

2) For each possible “cutoff” value for audiogram and speech test, determine % of individuals below cutoff who fall in bottom 10th percentile normal

3) Could also be adapted to simulated noise, HPDs, etc.
Unlike current standard, table will take into account differences in audiogram for individuals in the H3 category.

Putting it All Together

Two-dimensional “Risk Analysis” table...
A second approach involves use of hearing loss simulators

1) Recruit trained operators with normal hearing

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

3) Measure operational performance as a function of simulated hearing acuity

**Mission Objectives:**

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

4-8 players in each round

Data collected for total of 56 players
Hearing Loss Simulation
Elevated Thresholds

<table>
<thead>
<tr>
<th>Round</th>
<th>Participant 1</th>
<th>Participant 2</th>
<th>Participant 3</th>
<th>Participant 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Loss</td>
<td>H2-H3 Line</td>
<td>70th %tile</td>
<td>Profound</td>
</tr>
<tr>
<td>2</td>
<td>H2-H3 Line</td>
<td>70th %tile</td>
<td>Profound</td>
<td>No Loss</td>
</tr>
<tr>
<td>3</td>
<td>70th %tile</td>
<td>Profound</td>
<td>No Loss</td>
<td>H2-H3 Line</td>
</tr>
<tr>
<td>4</td>
<td>Profound</td>
<td>No Loss</td>
<td>H2-H3 Line</td>
<td>70th %tile</td>
</tr>
</tbody>
</table>

Hearing loss may have little impact on survivability....
But individuals with profound hearing loss eliminate far fewer players…..
- Hearing impaired individuals “cower and hide”

Hearing loss seems to have even greater impact in environments with impaired sight lines (i.e. not snow)
Hearing Loss Simulation: Binaural Degradation

Current phase of data collection....

Binaural Degradation:
- Normal detection thresholds
- Explore full range of localization error (azimuth)
- Swap Gain parameter controls mixing ratio between Left and Right signals

The results show that degraded localization had a greater impact on combat performance than degraded audibility....

.... But that listeners were much less aware of localization impairment than they were of hearing impairment.

Results suggest that they may have made decisions based on incorrect localization information, leading to bad outcomes.
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”

Effect of impaired communication on command and control effectiveness

Next Steps

- Thus far, experiments have primarily been conducted on untrained volunteers

- Next step is to conduct studies in field with service members trained in combat

- Studies will use HITS system
  - Battlefield-wide tracking of movements and actions

Auditory Processing in Blast-Exposed Listeners

Many military and VA audiologists report seeing patients with normal audiograms with complaints similar to those seen in older listeners

  - Difficulty understanding speech in crowded restaurants, etc.
Auditory Processing in Blast-Exposed Listeners

Performance on tests of central auditory processing by individuals exposed to high-intensity blasts

Gallun, Diedesch, Kubli, Walden, Folmer, Lewis, McDermott, Fausti, Leek (2012) JRRD, 49 (7); Pages 1005 — 1024

Showed 44% of Blast Exposed listeners with normal audiograms were abnormal on two or more Central Auditory Processing Tests (vs 10% for normals)

Approaches for Evaluating Real-World Listening

Approach 1:

Use stimuli that simulate complex real-world environments
**Auditory Processing in Blast-Exposed Listeners**

### Modified Version of Clinical “QuickSIN” test

<table>
<thead>
<tr>
<th>Test Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qsin</td>
<td>Standard clinical QuickSIN with a 4-talker babble masker</td>
</tr>
<tr>
<td>QSin_{\text{NOS}}</td>
<td>4-talker babble-masker with 180° interaural phase shift in target</td>
</tr>
<tr>
<td>QSin_{\text{AV}}</td>
<td>4-talker babble-masker with a video of the talker</td>
</tr>
<tr>
<td>QSin_{\text{AV/NOS}}</td>
<td>4-talker babble-masker video of talker and 180° phase shift</td>
</tr>
<tr>
<td>QSin_{\text{SP}}</td>
<td>Spatial condition with two 4-talker babble maskers at +/- 90°</td>
</tr>
<tr>
<td>QSin_{\text{SP/RV}}</td>
<td>Spatial condition with maskers at +/-90, simulated room reverberation</td>
</tr>
<tr>
<td>QSin_{\text{SP/RV/TC}}</td>
<td>Spatial condition with simulated reverb, and time-compressed talker</td>
</tr>
<tr>
<td>QSin_{\text{Noise}}</td>
<td>Condition with speech-shaped noise replacing the target talker</td>
</tr>
</tbody>
</table>

**Binaural Processing: Masking Level Difference**

### Masking Level Difference for Speech and Noise

- **500 Hz Tone N_{O,S_n}:** Baseline threshold for 50% detection of diotic tone in diotic noise
- **500 Hz Tone N_{O,S_{n}}:** Threshold for 50% detection of tone with in 180° phase shift
- **500 Hz Tone MLD:** Difference between N_{O,S_0} and N_{O,S_n} thresholds
Masking Level Difference for Speech and Noise

500 Hz Tone $N_0S_0$: Baseline threshold for 50% detection of diotic tone in diotic noise

500 Hz Tone $N_0S_\pi$: Threshold for 50% detection of tone with 180° phase shift

500 Hz Tone MLD: Difference between $N_0S_0$ and $N_0S_\pi$ thresholds

Spondee $N_0S_0$: Baseline threshold for 50% detection of diotic tone in diotic noise

Spondee $N_0S_\pi$: Threshold for 50% detection of tone with 180° phase shift

Spondee MLD: Difference between $N_0S_0$ and $N_0S_\pi$ thresholds

Self-Reported Survey

Hearing Self-Assessment

Listeners completed a 20-item self-assessment on their hearing, primarily from SSQ, e.g.

‘You are talking to someone on the telephone and someone next to you starts talking. Can you follow what is being said by both speakers?’

‘You are talking to a person. There is continuous background noise, such as a fan or running water. Can you follow what the person says?’

‘In the street, can you tell how far away someone is, from the sound of their voice or footsteps?’

‘Can you tell from the sound whether a bus or truck (vehicle) is coming towards you or going away?’

‘Do you have the impression of sounds being where you would expect them?’

‘Can you easily judge another person’s mood by the sound of their voice?’

‘Do everyday sounds that you hear seem to have an artificial or unnatural quality? (11 - Score)’

‘Can you easily ignore other sounds when trying to listen to something?’

‘Can you easily distinguish different pieces of music that you are familiar with?’
Auditory Processing in Blast-Exposed Listeners

Typical Pattern...

Blast slightly worse on all measures...

But not notably worse on any...

Exception is QSin_{SP+REV+TC}

Blast-exposed group includes mixture of normal and impaired listeners
- This makes traditional descriptive statistics relatively insensitive
- Better strategy is to look at cumulative distributions

25% of Blast Group in bottom 5 percentile
Putting it All Together
Evaluating Blast-Exposed Listeners

QuickSin with Reverb and Time Compression More Sensitive

Spatial QuickSin with Reverb and TC

Proportion of Subjects with Score: Value: Bin: Chart

40% of Blast Group in bottom 5 percentile

40% of Blast Group in bottom 5 percentile

Putting it All Together
Evaluating Blast-Exposed Listeners

500 Hz Tone N₀Sₙ most sensitive to blast exposure

500 Hz Tone N₀Sₙ Threshold (from MLD)

Proportion of Subjects with Score: Value: Bin: Chart

45% of Blast Group in bottom 5 percentile

45% of Blast Group in bottom 5 percentile
Putting it All Together
Evaluating Blast-Exposed Listeners

Combination of 500 Hz Tone N0S− Threshold with difference between QSin\textsubscript{SP RV TC} and QSin\textsubscript{SP RV TC} appears to be optimal screening tool

Very sensitive, clinically efficient, and aligned with complaint

55% of Blast Group in bottom 5 percentile

Evaluation of all tests in terms of percentage of impaired listeners in bottom 5\textsuperscript{th} pctile
Approaches for Evaluating Real-World Listening

Approach 2:

Use complex tasks that measure speech intelligibility indirectly, through behavior

Sentence Localization by Topic

The topic is “Sports”
He likes to swim in the morning

Christmas is my favorite time of year

Her brother is visiting next week

Blast exposed listeners are normal with one source, but orient more slowly to target in multitalker situations.
Ongoing Study-
Aurally-Aided Visual Search

Possibility of latent performance issues makes it important to test complex, multisensory integration tasks in fitness-for-duty evaluation.

Ongoing test: MRMC-funded effort to evaluate aurally-aided visual search ability in normal and blast-exposed listeners, both standing and walking.

64-channel Speaker Array installed behind screen in CAREN facility.

CAREN Study

Patients first perform a localization task.

Then an aurally-aided visual-search task...

Both stationary and while walking.
Other Blast / TBI Studies

**Breacher Study**

**15- Year Natural History Study**

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**Conclusions and Next Steps**

Impaired hearing negatively impacts operational performance
- In some cases, it also promotes unwanted changes in behavior

There is substantial variability in functional performance among H3s
- Suggests that audio thresholds alone are a poor AFFD measure

Small threshold shifts are unlikely to be catastrophic
- A good outcome, as it supports use of hearing protection

---
Conclusions and Next Steps

Impaired hearing negatively impacts operational performance
- In some cases, it also promotes unwanted changes in behavior

There is substantial variability in functional performance among H3s
- Suggests that audio thresholds alone are a poor AFFD measure

Small threshold shifts are unlikely to be catastrophic
- A good outcome, as it supports use of hearing protection

Questions remain-
- How should we account for HPD use in hearing impaired?
- Can we provide amplification to restore normal hearing?
- Do we need to screen H1 listeners for functional performance?