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

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Chief Scientist

National Military Audiology and Speech Pathology Center

Walter Reed Bethesda

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## 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*

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## Introduction

# Auditory Fitness for Duty: A Review

DOI: 10.3766/jaaa.20.9.3

Jennifer B. Tufts*
Kristin A. Vasil*
Sarah Briggs*

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

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## 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 know 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 warn on a combat patrol?
- Should a weapon system be quieted despite loss of capability?

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## 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

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## 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

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## 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?**

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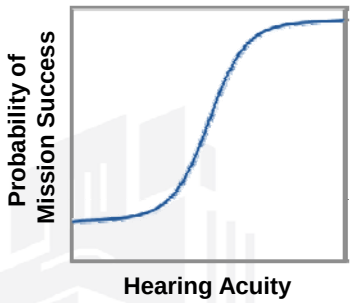
## Evaluating Operational Impact of Hearing Impairment

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*

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## Hearing Loss in the Military

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

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## Evaluation of Fitness for Duty

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?*

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# Identifying Mission Critical Auditory Tasks (MCATs)

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## 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[1]

**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[1]

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## 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

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## 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 |

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## Identifying MCATS

Which of the 17 auditory tasks are mission critical?

Method:
- Questionnaire with Likert scale ratings
- 87 infantry personnel
- Quantitative analysis

| CONSEQUENCES of poor performance | WHO performs this task? | FREQUENCY of task |
|---|---|---|
| In your opinion how significant are the consequences of poor performance on this task? | In your opinion, during a training exercise or when serving on a tour of duty is this task carried out by all infantry personnel, some infantry personnel or no infantry personnel? | In your opinion, how frequently is this task performed during a training exercise or when serving on a tour of duty? |
| 1 = No Consequence<br>2 = Minor<br>3 = Moderate<br>4 = Major<br>5 = Critical | 1 = No infantry personnel<br>2 = Some infantry personnel (indicate which roles)<br>3 = All infantry personnel | 1 = Seldom or yearly<br>2 = Occasionally or monthly<br>3 = Regularly or weekly<br>4 = Frequently or daily<br>5 = Continuously or several times per day |

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## Identifying MCATS

| Frequency of task performance | Consequences of poor performance: No consequence | Minor | Moderate | Major | Critical |
|---|---|---|---|---|---|
| Seldom or yearly | | | | | |
| Occasionally or monthly | | | T17 | T10 T12 | |
| Regularly or weekly | | | T11 T13 T14 T16 | T15 | T1 T6 T9 |
| Frequently or daily | | | | T2 T3 T4 T7 | T5 |
| Continuously or several times per day | | | | | |

| |
|---|
| **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** |

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## Clinical Tools to Assess Fitness for Duty

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## 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**

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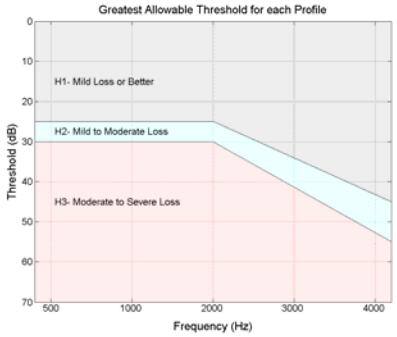
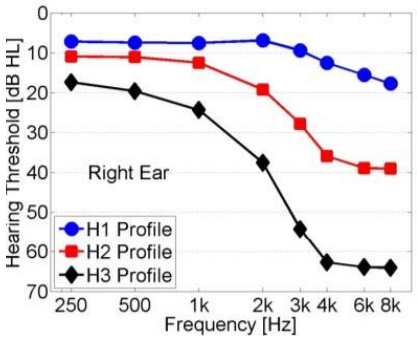
## Clinical Tools to Efficiently Assess Hearing Loss

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

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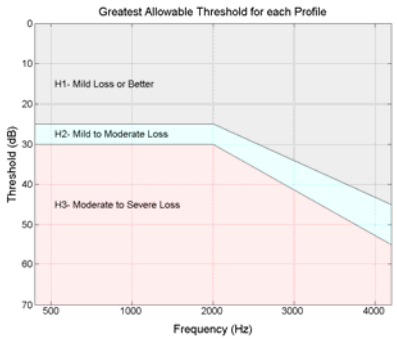
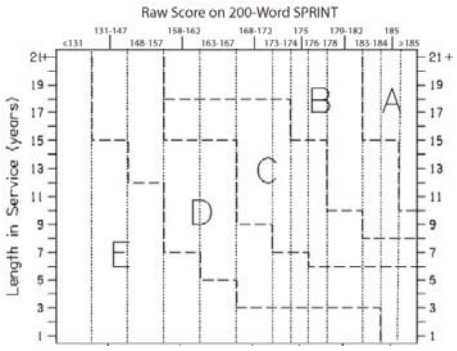
## Clinical Tools to Efficiently Assess Hearing Loss

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

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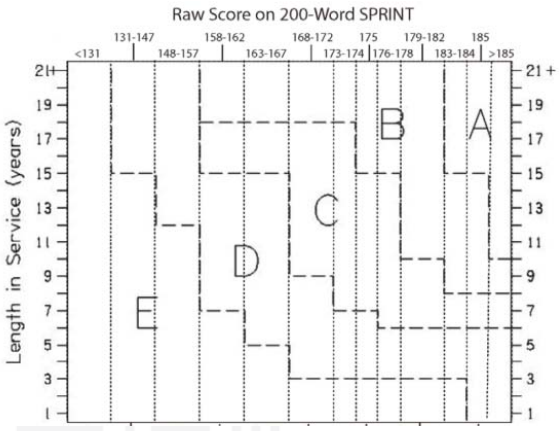
## Assessment of Fitness for Duty

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




| Category | Recommendation |
|---|---|
| A | Retention in current assignment |
| B | Retention in current assignment with restrictions |
| C | Re-assignment to (or retention in) non-noise hazardous AOC/MOS |
| D | Discretionary (audiologist chooses between C or E) |
| E | Separation from Service |

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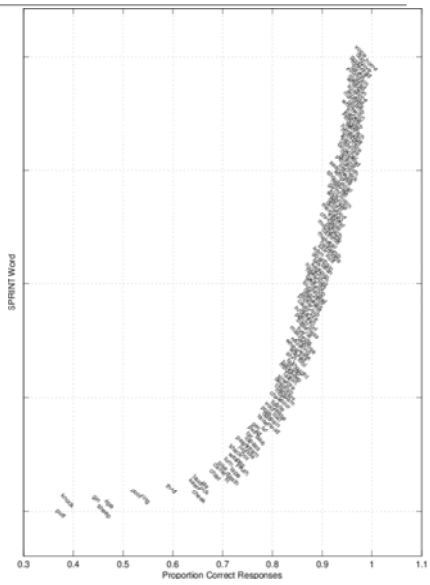
## Re-Evaluation of the SPRINT Test

The 200-word SPRINT is a long test

It takes 20 minutes to complete

Is there a way to increase efficiency?



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## Re-Evaluating the SPRINT Test

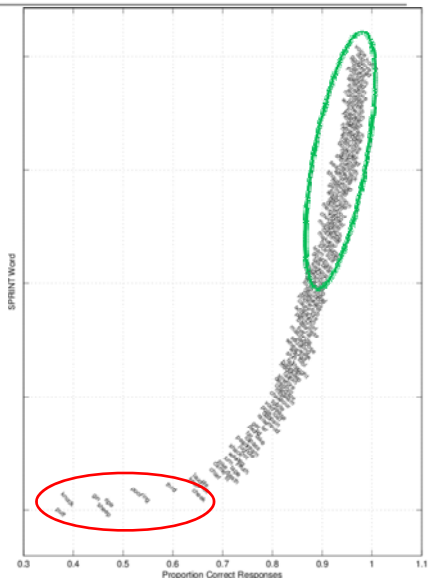
The 200-word SPRINT is a long test

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

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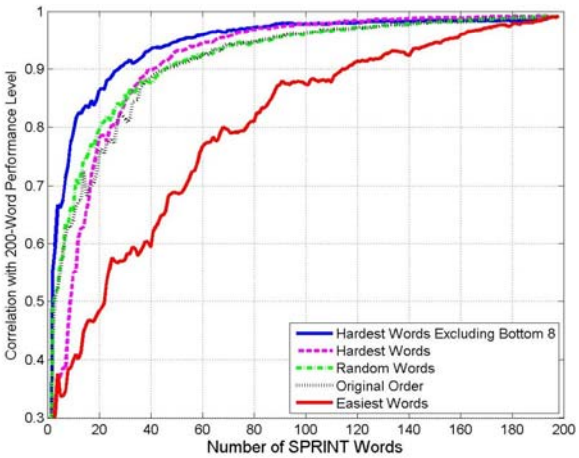
## Re-Evaluating the SPRINT Test

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



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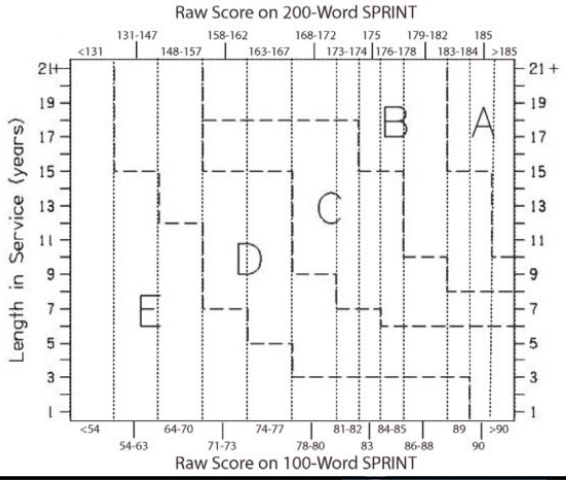
## New 100-word SPRINT Test

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




James.d.hite.civ@mail.mil
USAPHC Army Hearing Program
5158 Blackhawk Rd, Bldg E-1570
Edgewood, MD 21010-5403

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## 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

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## 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

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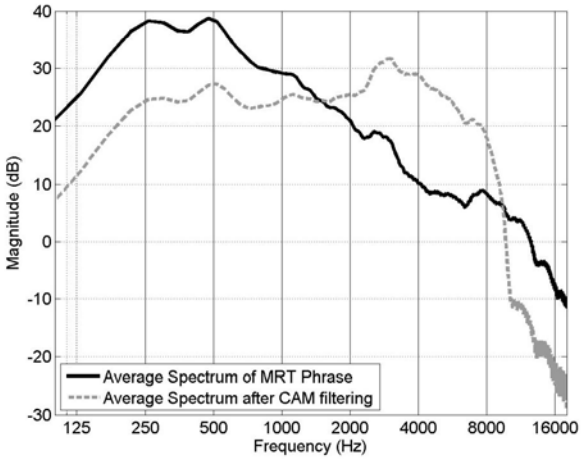
## Speech-in-Noise Tests for Auditory Fitness-for-Duty

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

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## 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

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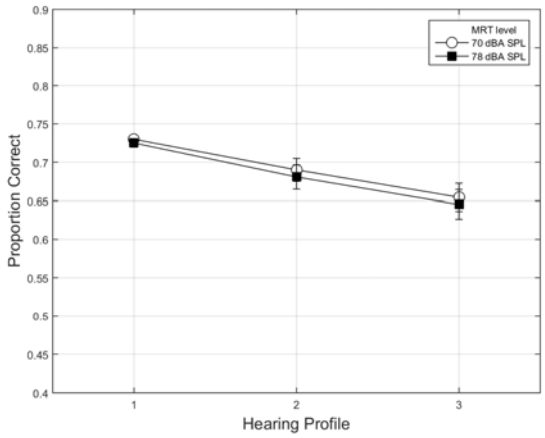
## Speech-in-Noise Tests for Auditory Fitness-for-Duty: MRT




Overall level has no impact on performance - even for H3
This implies that MRT measured "distortion" not "audibility"

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## Tablet-Based Test Procedure

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)

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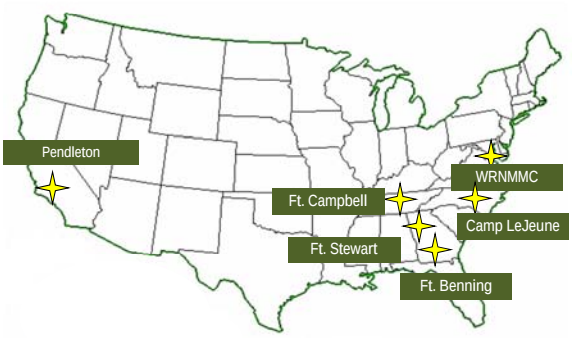
## FIT Test Sites

**Active FIT Sites**

- WRNMMC
- Ft. Campbell
- Ft. Benning
- Camp LeJeune
- Pendleton
- Ft. Stewart



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## FIT Test Sites

**Proposed FIT Sites**

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



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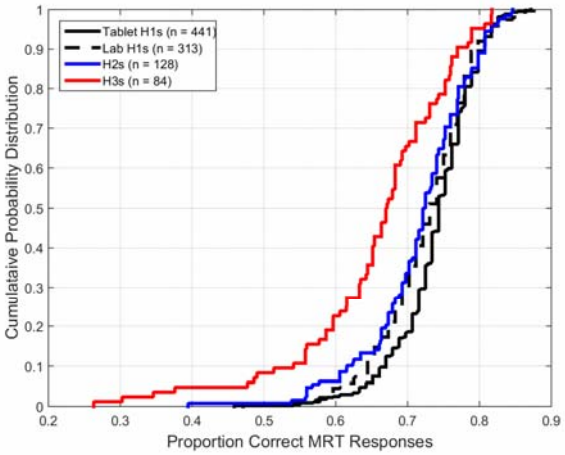
## Speech-in-Noise Tests for Auditory Fitness-for-Duty: MRT

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## Test Operational Sounds on Hearing Impaired Listeners

First approach:

Measure real operational sounds in field…

Test on real hearing impaired listeners

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## 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

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## 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)



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## 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

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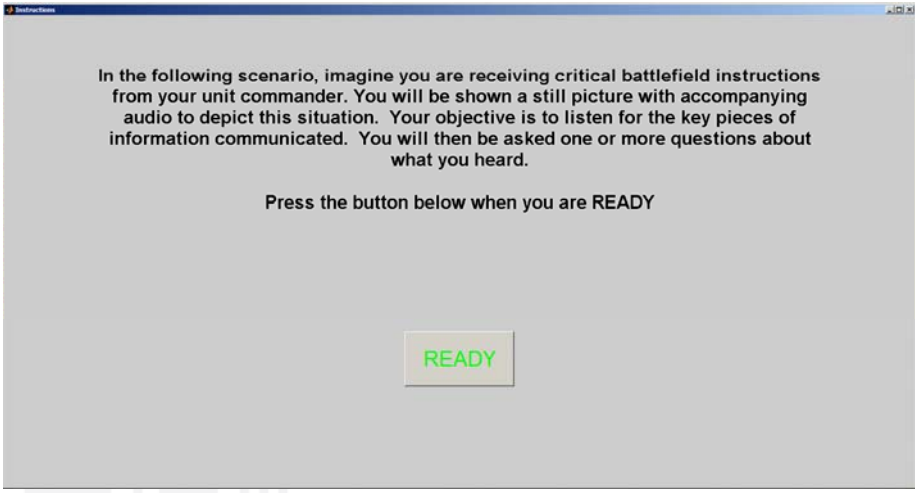
## Ft Polk Operational Tests

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## Ft Polk Operational Tests

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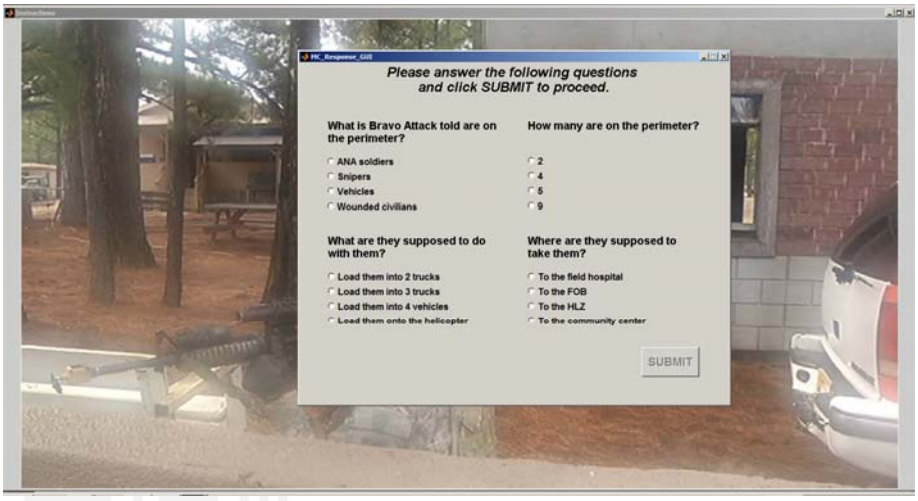
## Ft Polk Operational Tests

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## Ft Polk Operational Tests

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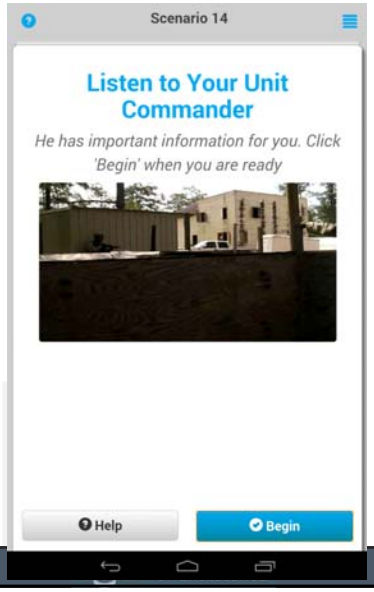
## Ft Polk Operational Tests

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## Ft Polk Operational Tests

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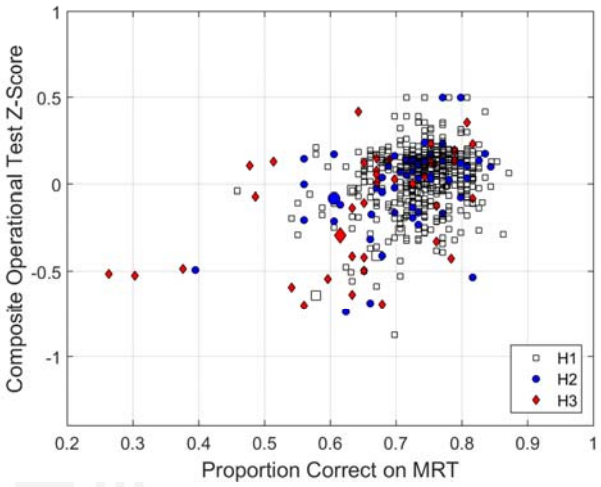
## Ft Polk Operational Tests

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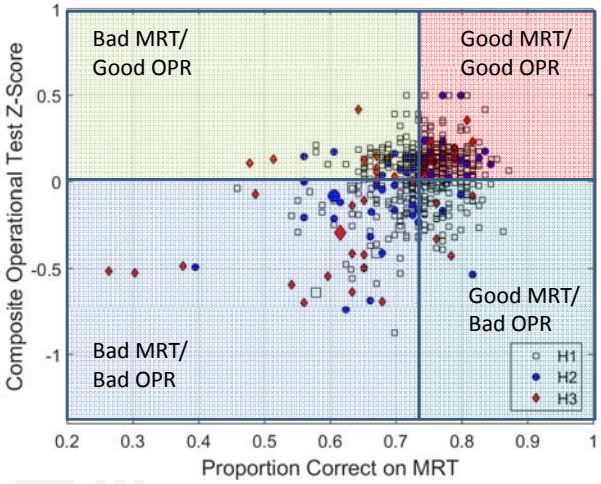
## Ft Polk Operational Tests

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## 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 DOEHRS-HC audiogram

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## 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.

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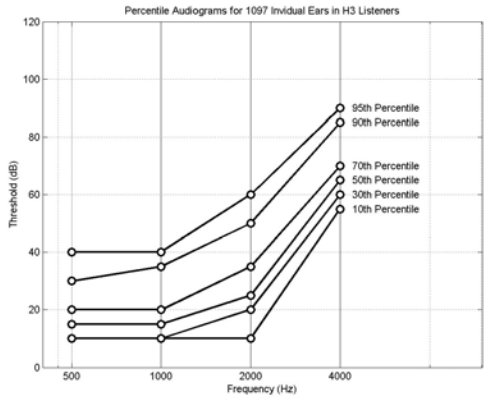
## Putting it All Together

Unlike current standard, table will take into account differences in audiogram for individuals in the H3 category….

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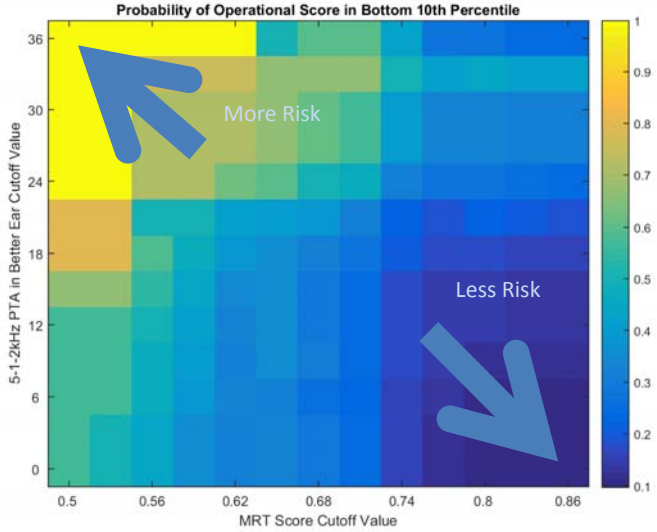
## Putting it All Together

Two-dimensional "Risk Analysis" table…



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## Approach 2: Simulate Impaired Hearing in the Field

**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


U.S. Army Public Health Command USAPHC

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## Hearing Loss Simulation Elevated Thresholds

**Paintball version of "Hunger Games"**

**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**

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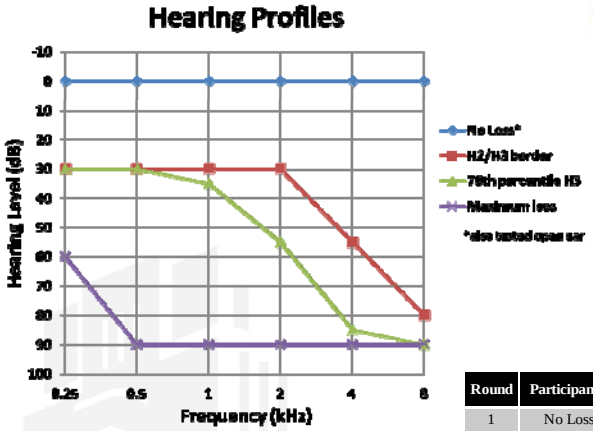
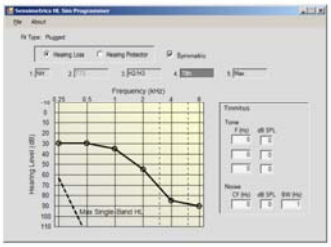
## Hearing Loss Simulation Elevated Thresholds



| Round | Participant 1 | Participant 2 | Participant 3 | Participant 4 |
|---|---|---|---|---|
| 1 | No Loss | H2/H3 Line | 70th %tile | Profound |
| 2 | H2/H3 Line | 70th %tile | Profound | No Loss |
| 3 | 70th %tile | Profound | No Loss | H2/H3 Line |
| 4 | Profound | No Loss | H2/H3 Line | 70th %tile |

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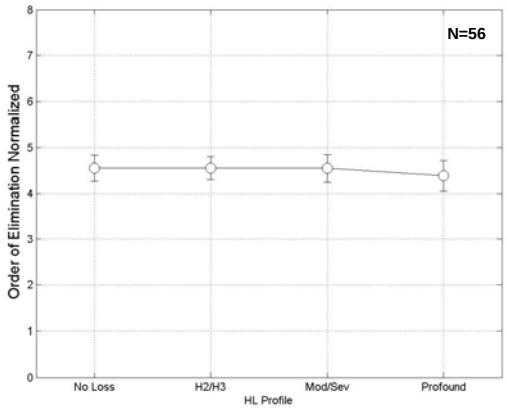
## Hearing Loss Simulation Elevated Thresholds

**Hearing loss may have little impact on survivability….**

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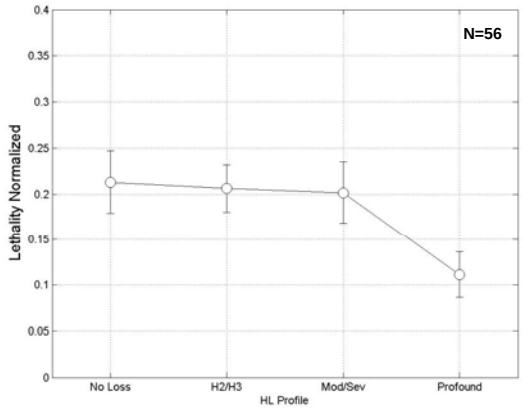
## Hearing Loss Simulation Elevated Thresholds

**But individuals with profound hearing loss eliminate far fewer players…..**

- **Hearing impaired individuals "cower and hide"**

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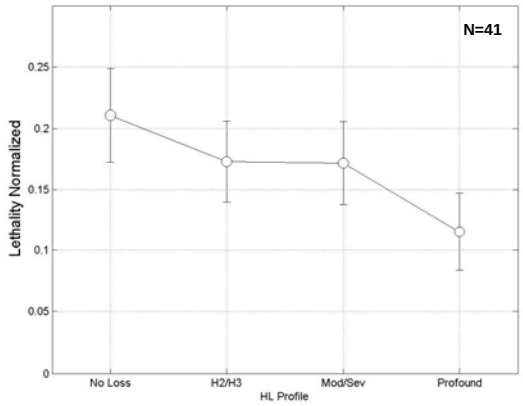
## Hearing Loss Simulation Elevated Thresholds

**Hearing loss seems to have even greater impact in environments with impaired sight lines (i.e. not snow)**

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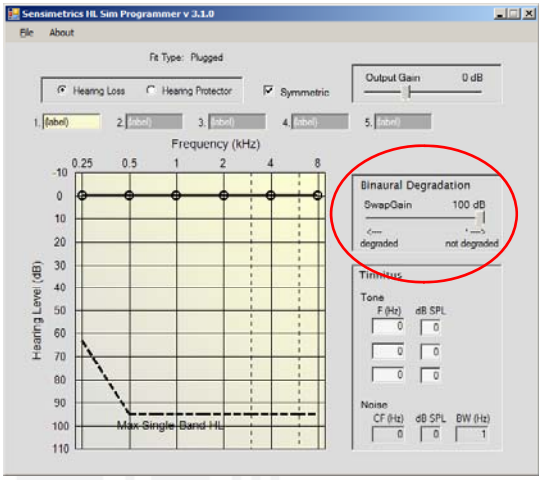
## Hearing Loss Simulation: Binaural Degradation

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

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## Hearing Loss Simulation: Binaural Degradation

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

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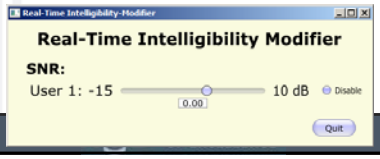
## Hearing Loss Simulation Impaired Intelligibility

**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"**

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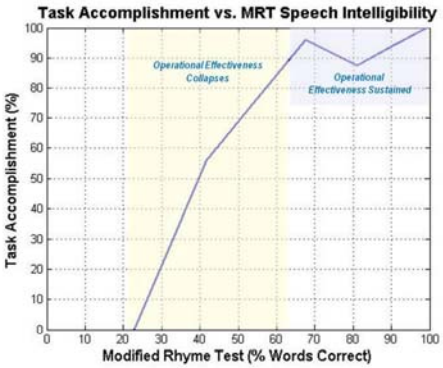
## Hearing Loss Simulation Impaired Intelligibility

**Effect of impaired communication on command and control effectiveness**

**Aegis Simulator**

**NSWC - Dahlgren, VA**




Mentel, K., Ziriax, J., Dachos, J., Salunga, A., Turner, H., Sheffield, B., Brungart, D. (2013). *The relationship between speech intelligibility and operational performance in a simulated naval command information center.* Human Factors and Ergonomics Society Annual Meeting. San Diego, CA.

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## 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

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## 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.

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## Auditory Processing in Blast-Exposed Listeners

JRRD Department of Veterans Affairs Rehabilitation Research & Development Service
Journal of Rehabilitation Research & Development

**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)

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## Approaches for Evaluating Real-World Listening

Approach 1:

Use stimuli that simulate complex real-world environments

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## Auditory Processing in Blast-Exposed Listeners

### Modified Version of Clinical "QuickSIN" test

Qsin - Standard clinical QuickSIN with a 4-talker babble masker

$QSin_{N0S\pi}$- 4-talker babble-masker with 180° interaural phase shift in target

$QSin_{AV}$– 4-talker babble-masker with a video of the talker

$QSin_{AV/N0S\pi}$– 4-talker babble-masker video of talker and 180° phase shift

$QSin_{SP}$– Spatial condition with two 4-talker babble maskers at +/- 90°

$QSin_{SP+RV}$– Spatial condition with maskers at +/-90, simulated room reverberation

$QSin_{SP+RV+TC}$– Spatial condition with simulated reverb, and time-compressed talker

$QSin_{Noise}$– Condition with speech-shaped noise replacing the target talker

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## Binaural Processing: Masking Level Difference

### 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 in 180° phase shift

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

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## Binaural Processing: Masking Level Difference

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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 in 180° phase shift

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

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## 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?'

'Do you have to concentrate very much when listening to someone or something? (11 - Score)'

'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?'

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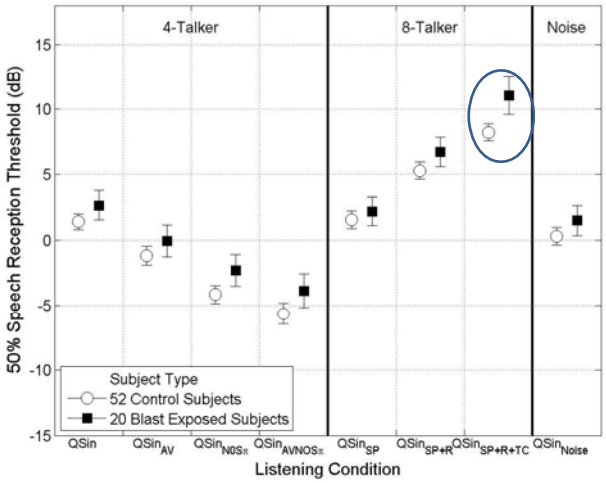
## Auditory Processing in Blast-Exposed Listeners




**Typical Pattern…**

**Blast slightly worse on all measures…**

**But not notably worse on any…**

**Exception is $QSin_{SP+REV+TC}$**

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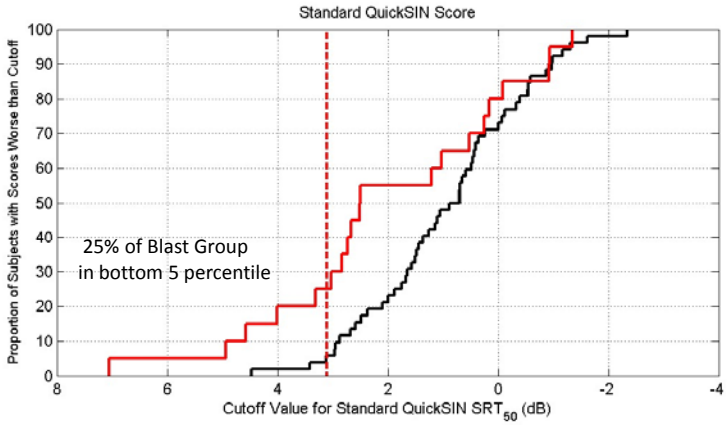
## Putting it All Together Evaluating Blast-Exposed Listeners

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

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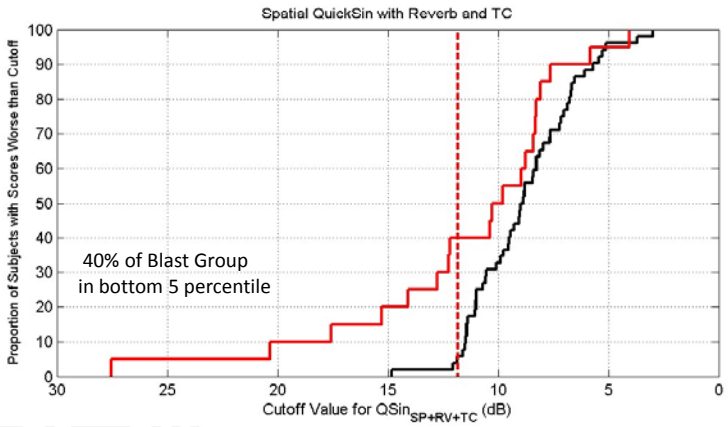
## Putting it All Together
## Evaluating Blast-Exposed Listeners

QuickSin with Reverb and Time Compression More Sensitive

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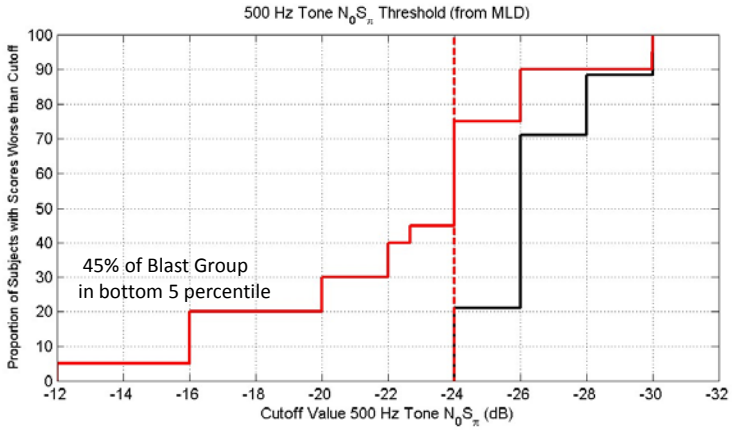
## Putting it All Together
## Evaluating Blast-Exposed Listeners

500 Hz Tone $N_0S_\pi$ most sensitive to blast exposure

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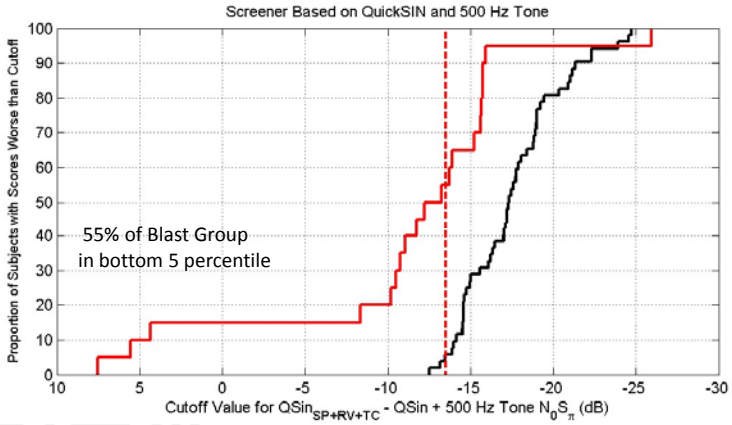
## Putting it All Together
## Evaluating Blast-Exposed Listeners

Combination of 500 Hz Tone $N_0S_\pi$ Threshold with difference between $QSin_{SP+RV+TC}$ and $QSin_{SP+RV+TC}$ appears to be optimal screening tool

Very sensitive, clinically efficient, and aligned with complaint

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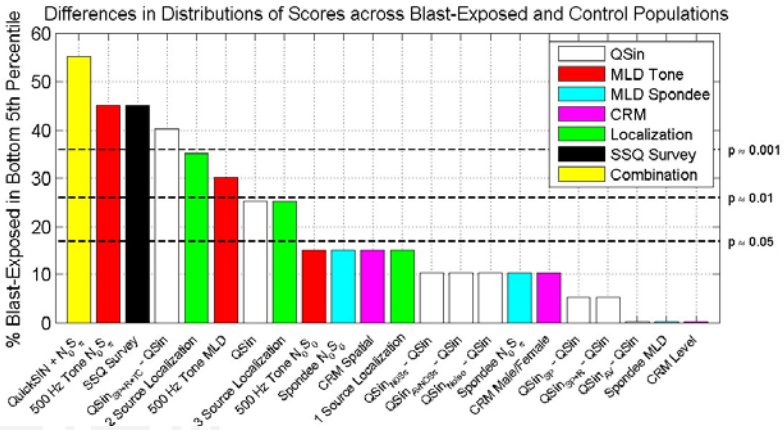
## Putting it All Together
## Evaluating Blast-Exposed Listeners

Evaluation of all tests in terms of percentage of impaired listeners in bottom 5th pctile

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## Approaches for Evaluating Real-World Listening

### Approach 2:

Use complex tasks that measure speech intelligibility indirectly, through behavior

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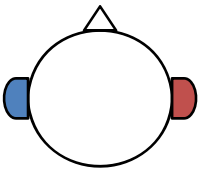
## Sentence Localization by Topic

The topic is "Sports"

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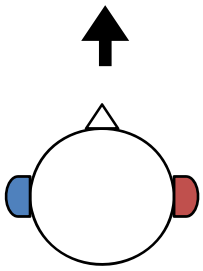
## Sentence Localization by Topic

He likes to swim in the morning



Christmas is my favorite time of year

Her brother is visiting next week

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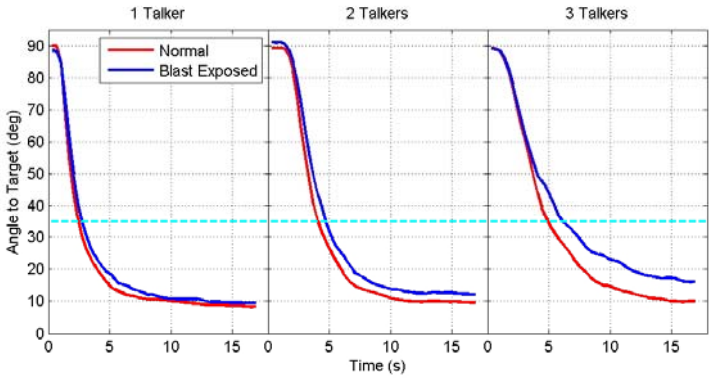
## Sentence Localization by Topic

Blast exposed listeners are normal with one source,
but orient more slowly to target in multitalker situations

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## Ongoing Study- Aurally-Aided Visual Search

Possibility of latent performance issues makes it important to test complex, multsensory 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….

NICoE National Intrepid Center of Excellence

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## CAREN Study

Patients first perform a localization task

Then an aurally-aided visual-search task…

Both stationary and while walking

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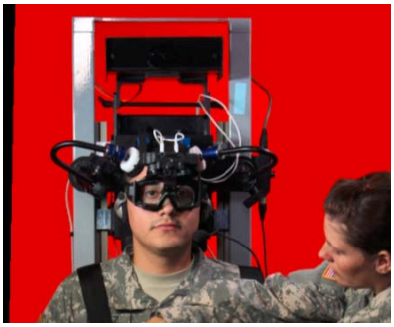
## Other Blast / TBI Studies

**Breacher Study**

**15- Year Natural History Study**



DVBIC
Defense and Veterans Brain Injury Center

HCE Department of Defense Hearing Center of Excellence

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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

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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
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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?

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