Blast Exposure, mild Traumatic Brain Injury (mTBI) and Auditory Rehabilitation

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National Center for Rehabilitative Auditory Research (NCRAR)

http://www.ncrar.research.va.gov/
Why are we interested in this?

Data show that:

- About 300,000 Operation Enduring Freedom (OEF)/Operation Iraqi Freedom (OIF) Veterans have some form of traumatic brain injury (TBI)

- About 75% of wounds are due to exposure to a blast(s)

66% of Veterans with deployment-related TBI and blast complained of auditory difficulties. Of these:

- 35-54% have SNHL
- 7% conductive (ruptured TM)
- 20% have ‘normal or almost normal’ thresholds

Saunders & Echt (2012), JRRD, 49(7): 1043-1058 2012
Subjective impacts

- Hearing in background noise
- Following rapid speech
- Following instructions
- Following long conversations
- Tinnitus
- Hyperacusis

{i.e. indicative of auditory processing problems}
High pressure wave is generated, followed by a vacuum

**Primary injuries**
- Contusions (bruising) from brain moving within skull
- Hemorrhage from tearing of surface veins during movement
- Diffuse axonal injury as neurons are sheared and stretched

**Secondary injuries**
Damage from flying objects

**Tertiary injuries**
Damage when person is thrown into a solid object
Blast damage to the auditory system

Peripheral Damage

- Pinna damage: burns/damage from flying debris
- Rupture of the tympanic membrane from pressure wave
- Ossicular disruption from pressure wave
- Blast wave damages to semicircular canals causing vestibular problems
- Blast wave and noise damages hair cells and basilar membrane in cochlea
Damage to central auditory system - MRI following blast exposure

Contusions (blue) - brain moving within skull causing bruising
Hemorrhage (purple) - brain moving in skull tears surface veins

Frontal/pre-frontal cortex
  Attention/listening

Temporal cortex
  Feature-specific auditory processing

Parietal lobe
  Spatial processing

Occipital lobe
  Visual processing

Cerebellum
  Balance

Diffuse axonal injury (pink) - shearing & stretching of neurons

Evaluation of Approaches to Auditory Rehabilitation for mTBI

Research team:
Gabrielle Saunders, Terry Chisolm, Paula Myers, Melissa Teahen, Michelle Arnold, ShienPei Silverman

Study funded by VA RR&D grant #: C7054R
Reported difficulties:

- Hearing in background noise
- Following rapid speech
- Following instructions and long conversations
- Tinnitus
- Hyperacusis

Signal-to-noise ratio (SNR)

Temporal processing

Working memory
Interventions

**FM system**
- Will be effective at improving SNR, if used correctly
- A prop rather than a ‘fix’; requires an external device

**Auditory Training**
- Potential for sustainable change (a fix) for processing difficulties.
- Requires discipline and time commitment before any benefit may be realized.
Interventions

- Phonak Zoomlink transmitter and binaural iSense receivers

- Brain Fitness Program - computer-based training program developed by Merzenich et al., distributed by Posit Science.
  
  Designed to train:
  - Temporal processing
  - Auditory working memory
  - 40 sessions, 60 min/day
The Brain Fitness Program: Training Tasks

- **High or Low?**
- **Tell Us Apart**
- **Match It!**

- **Sound Replay**
- **Listen and Do**
- **Story Teller**
Participants

- OEF/OIF Veterans
- Normal or near normal peripheral hearing sensitivity
- Reported blast exposure during deployment
- Self-reported functional hearing difficulties
- Recruited from Portland and Tampa VA medical centers
2-site randomized controlled clinical trial

Consenting, Screening
Baseline Testing

Random assignment to intervention

Counseling (Control)
Counseling + Auditory Training
Counseling + FM System
Counseling + Auditory Training + FM System

8-12 weeks

Post-intervention testing
## Outcome Measures: Performance

<table>
<thead>
<tr>
<th>Test measure</th>
<th>Rationale for Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap detection - Adaptive Tests of Temporal Resolution</td>
<td></td>
</tr>
<tr>
<td>ATTR</td>
<td></td>
</tr>
<tr>
<td>Time Compressed Speech</td>
<td></td>
</tr>
<tr>
<td>Working memory - Digit Span Test WAIS III</td>
<td></td>
</tr>
<tr>
<td>Dichotic - Staggered Spondaic Word test (SSW)</td>
<td></td>
</tr>
</tbody>
</table>
Staggered Spondaic Word Test (SSW)

Four Test Conditions:

- Right non-competing (RNC)
- Right competing (RC)
- Left competing (LC)
- Left non-competing (LNC)
## Outcome Measures: Performance

<table>
<thead>
<tr>
<th>Test measure</th>
<th>Rationale for Testing</th>
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</thead>
<tbody>
<tr>
<td>Gap detection - Adaptive Tests of Temporal Resolution ATTR</td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Working memory - Digit Span Test WAIS III</td>
<td></td>
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<tr>
<td>Dichotic - Staggered Spondaic Word test (SSW)</td>
<td></td>
</tr>
<tr>
<td>Attention/Interference - Stroop Color Word Test</td>
<td></td>
</tr>
</tbody>
</table>
Stroop Test

Read word

RED  GREEN  RED  BLUE  GREEN  RED  BLUE

Read color word is printed in - without squinting!

RED  GREEN  RED  BLUE  GREEN  RED  BLUE
### Outcome Measures: Performance

<table>
<thead>
<tr>
<th>Test measure</th>
<th>Rationale for Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap detection - Adaptive Tests of Temporal Resolution ATTR</td>
<td>Trained with AT</td>
</tr>
<tr>
<td>Time Compressed Speech</td>
<td>Trained with AT</td>
</tr>
<tr>
<td>Working memory - Digit Span Test</td>
<td>Trained with AT. May improve with FM use</td>
</tr>
<tr>
<td>WAIS III</td>
<td></td>
</tr>
<tr>
<td>Dichotic - Staggered Spondaic Word test (SSW)</td>
<td>Indications from other studies</td>
</tr>
<tr>
<td>Attention/Interference - Stroop Color Word Test</td>
<td>Trained with AT. May improve with FM use</td>
</tr>
<tr>
<td>Speech-in-noise - HINT</td>
<td>Will improve with FM.</td>
</tr>
</tbody>
</table>
## Self-Report Outcome Measures

<table>
<thead>
<tr>
<th>Test</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech Spatial and Qualities Questionnaire - comparative (SSQ-C)</td>
<td>Likely to improve with FM; may improve with AT</td>
</tr>
<tr>
<td>Cognitive Self-Report Questionnaire (CSRQ)</td>
<td>Some scales likely to improve following one or both interventions</td>
</tr>
<tr>
<td>Psychosocial Impact of Assistive Devices Scale (PIADS)</td>
<td>May improve following either intervention</td>
</tr>
</tbody>
</table>
Speech Spatial and Qualities Questionnaire - Comparative (SSQ-C)

- Designed to measure self-reported auditory disability for speech, spatial processing and sound quality relative to before intervention.

### Speech Spatial and Qualities Questionnaire- Compare (SSQ-C)

#### You are talking with one other person and there is a TV on in the same room. Without turning the TV down, can you follow what the person you’re talking to says?

Comparing your ability now with your ability before this study

<table>
<thead>
<tr>
<th>Much worse</th>
<th>Unchanged</th>
<th>Much better</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>-4</td>
<td>-3</td>
</tr>
<tr>
<td>-2</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>+1</td>
<td>+2</td>
<td>+3</td>
</tr>
<tr>
<td>+4</td>
<td>+5</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

#### You are talking with one other person in a quiet, carpeted lounge-room. Can you follow what the other person says?

Comparing your ability now with your ability before this study

<table>
<thead>
<tr>
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<th>Unchanged</th>
<th>Much better</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-3</td>
</tr>
<tr>
<td>-2</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>+1</td>
<td>+2</td>
<td>+3</td>
</tr>
<tr>
<td>+4</td>
<td>+5</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
Cognitive Self Report Questionnaire (CSRQ)

- A 64-item questionnaire assessing daily functioning on 8 subscales:
<table>
<thead>
<tr>
<th></th>
<th>Less often</th>
<th>Same as before</th>
<th>More often</th>
<th>Does not apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>I lose my train of thought...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My ability to pay attention to more</td>
<td>Better</td>
<td>Same as before</td>
<td>Worse</td>
<td>Does not apply</td>
</tr>
<tr>
<td>than one thing at a time is...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My ability to remember phone numbers</td>
<td>Better</td>
<td>Same as before</td>
<td>Worse</td>
<td>Does not apply</td>
</tr>
<tr>
<td>My ability to hear things clearly is</td>
<td>Better</td>
<td>Same as before</td>
<td>Worse</td>
<td>Does not apply</td>
</tr>
</tbody>
</table>
Psychosocial Impact of Assistive Devices Scale (PIADS)

- A 26-item questionnaire assessing the impact of assistive devices on perceived:
  
  Competence
  
  Adaptability
  
  Self-esteem

Day et al. (2001), Disabil Rehabil 23(9):400-404
Each word or phrase describes how using the ___________ * might affect you.

Wording is adapted for each intervention

* FM system/auditory training program /information we gave you
# Psychosocial impact of Assistive Devices Scale (PIADS)

<table>
<thead>
<tr>
<th></th>
<th>Decreases</th>
<th>No change</th>
<th>Increases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
</tr>
<tr>
<td>Competence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Happiness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequacy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-esteem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usefulness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well-being</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results

Data collected from 86 participants.

<table>
<thead>
<tr>
<th></th>
<th>FM+AT</th>
<th>AT</th>
<th>FM</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>22</td>
<td>15</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Age</td>
<td>33.1</td>
<td>34.8</td>
<td>33.9</td>
<td>33.7</td>
</tr>
<tr>
<td>4F-PTA</td>
<td>13.4</td>
<td>11.0</td>
<td>12.1</td>
<td>12.1</td>
</tr>
<tr>
<td>Gender</td>
<td>Male: 22 Female: 0</td>
<td>Male: 12 Female: 3</td>
<td>Male: 19 Female: 5</td>
<td>Male: 22 Female: 3</td>
</tr>
</tbody>
</table>
Baseline Performance

- Do these individuals have measurable performance deficits?

- No control group therefore will compare data with published norms
Listening in spatialized noise-sentences test (LISN-S)

Adaptive SRT

Target sentences: Blah blah blah

Competing sentences: Blah blah blah

Different voice Different location: SPATIAL ADVANTAGE

Different voice Same location: TALKER ADVANTAGE

Different voice Different location: TOTAL ADVANTAGE
Listening in spatialized noise-sentences test (LISN-S)

Normative data from Cameron et al (2011)

LISN-S

Talker Advantage

Spatial Advantage

Total Advantage

% participants

< normal ≥ normal

< normal ≥ normal

% participants

< normal ≥ normal
**ATTR - Gap detection**

- Below average performance: gap threshold +1 SD
- Data from ‘young’ adults)

![Bar chart showing percentage of participants below and above normal thresholds for within and across channel gap detection.]

Other measures

**HINT**

- 52% participants in < normal
- 48% participants in ≥ normal
Results

Did the participants use the interventions?
Compliance with intervention
Auditory Training

Percentage of Auditory Training Completed

- <25% sessions
- 25-49% sessions
- 50-74% sessions
- 75-100% sessions

n = 37

% participants
Compliance
FM System

- 1 individual did not use FM at all
- 13 wore it hardly ever
- 25 wore it a few times a week
- 7 used it every day

Average use per day = 2.9 hr, range: 0-9
Gap detection - All subjects

F=2.19, p=0.096, partial eta squared = 0.075
Speech-in-Noise - HINT

F = 2.11, p = 0.105, partial eta squared = 0.076
**Digit Span**

\[ F = 0.692, \ p = 0.560, \text{ partial } \eta^2 = 0.025 \]

![Bar graph showing benefit in digits for Forward and Backward conditions with FM, AT, FM + AT, and Control groups.](image-url)
F=0.789, p=0.504

Better

<table>
<thead>
<tr>
<th>Benefit (Total errors)</th>
<th>FM+AT</th>
<th>FM</th>
<th>AT</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SSQ-C

A graph showing the benefit levels for speech spatial qualities with ranges from -5 to +5. The graph compares different conditions: FM, AT, and FM + AT. The x-axis represents different qualities: speech, spatial, and qualities. The y-axis indicates the benefit levels. The graph includes error bars and statistical significance markers.
Significant differences across treatment arms for all scales except energy & satisfaction

Better [Range: -8 to +8]

- Attention
- Executive function
- Memory
- Language
- Vision
- Hearing
- Energy
- Satisfaction

Ctl, FM

* FM + AT
* FM
* AT
* Control
PIADS

Better [Range: -3 to +3]

-0.5 0.0 0.5 1.0 1.5

Competence  Adaptability  Self-esteem

FM + AT  FM  AT  Control
Interventions are showing some small but positive outcomes for

- temporal processing
- speech-in-noise
- Reported auditory difficulties
- Reported cognitive processing

Combination of AT and FM appears to be most effective

There are individual differences in compliance and in outcome
Many more analyses to conduct:

- Relationships between compliance and outcome
- Predictors of outcome (individual differences)
- Baseline deficit on outcome
Clinical take-home message

- Consider FM+AT for blast-exposed patients
- Make sure patient is open to using the interventions – or they likely won’t use them

Check out the new format for running Brain Fitness from Posit Science: [https://brainhq.positscience.com/octnl-free/start#](https://brainhq.positscience.com/octnl-free/start#)

Format allows user to direct their own training
Beyond the Audiology Clinic: Innovations and Possibilities of Connected Health

NCRAR Conference: September 18-20\textsuperscript{th} 2013

Elizabeth Krupinski, Ph.D. (Keynote)
Harvey Abrams, Ph.D. Terry Chisolm, Ph.D
Deborah Ferrari, Ph.D Louise Hickson, Ph.D.
Jeffrey Kaye, Ph.D. John Kokesh, M.D.
Robert Margolis, Ph.D. Jerry Northern Ph.D.
Chad Galdden, Au.D.
Presentations on

- Principles and methods underlying telemedicine
- How teleaudiology fits into the changing healthcare landscape
- Presentations about 2 established teleaudiology programs (Alaska and Brazil)
- State-of-the art in VA teleaudiology
- Automated hearing testing
- Tele-Aural Rehabilitation
- Attitudes towards telepractice
Old habits die hard.....
Thank you for listening
Gabrielle.saunders@va.gov
Blast wave physics

Highly pressurized gas expands →

**Peak Overpressure (shock wave)**

Shock wave travels through air rapidly expanding resulting in

**Negative underpressure**

→ **Secondary Overpressure**

Behind vacuum air rushes in = blast wind occurs

**Explosion** → Solid/liquid is converted into highly pressurized gas
Evaluation of Approaches to Auditory Rehabilitation for mTBI

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Study funded by VA RR&D grant #: C7054R
HINT – Performance and Perceptual
Gap detection – baseline performance below normal

Within-channel

Across-channel

F=1.17
n.s.

F=3.87
p=0.015
Performance-based impacts

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

Gallun et al, J Rehab Res Dev, 49(7) 1005-1024
Participants

36 blast-exposed OEF/OIF soldiers;
18 with mTBI
- Tested at Walter Reed Army Medical Center
- Treated for other blast related injuries
- Normal middle ear function
- Mean Age: 32.8 years

29 controls, matched to soldiers on age and hearing
- Tested at NCRAR
- Non-blast exposed
- Mean Age: 33.4 years
<table>
<thead>
<tr>
<th>Test</th>
<th>Site of lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audiometric evaluation</td>
<td>Sensorineural vs. conductive vs. none</td>
</tr>
<tr>
<td>Gaps in Noise (GIN)</td>
<td>Cortex; corpus callosum</td>
</tr>
<tr>
<td>Staggered Spondaic Word Test (SSW)</td>
<td>Cortex; corpus callosum</td>
</tr>
<tr>
<td>Masking Level Difference (MLD)</td>
<td>Brainstem</td>
</tr>
<tr>
<td>Frequency Pattern Test (FPT)</td>
<td>Cortex; corpus callosum; brainstem</td>
</tr>
<tr>
<td>Dichotic Digits Test (DDT)</td>
<td>Cortex; corpus callosum</td>
</tr>
<tr>
<td>Auditory Brainstem Response Waves I to VII</td>
<td>Auditory nerve to auditory cortex</td>
</tr>
<tr>
<td>Long-latency responses (N1, P2, P3)</td>
<td>Auditory cortex</td>
</tr>
</tbody>
</table>
Audiometric data

Blast Exposed Subjects
(n=36)

Control Subjects
(n=29)

Clinically normal hearing

Hearing Threshold (dB)

250 500 1000 2000 3000 4000 6000 8000

-10 0 10 20 30 40 50 60 70 80

X Left ear
○ Right ear
Performance test data

- Blast-exposed (n=36)
- Controls (n=29)

Abnormal score (% participants)

- Frequency Pattern Test
- GIN
- MLD
- Dichotic digits
- SSW

Participants (%)

- Number of Abnormal Test Results (of 5 Possible)
Long-Latency Potentials

- LE - Common
- LE - Rare
- RE - Common
- RE - Rare

Controls

Blast Exposed