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

Gabrielle Saunders, Ph.D.
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

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

Damage to central auditory system (cont.)

**Corpus callosum**
- Interhemispheric transfer

**Thalamus**
- Organization and updating of cortical-brainstem connections

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

Rehabilitation???

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 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>
</tr>
</thead>
<tbody>
<tr>
<td>Gap detection - Adaptive Tests of Temporal Resolution <strong>ATTR</strong></td>
<td></td>
</tr>
<tr>
<td>Time Compressed Speech</td>
<td></td>
</tr>
<tr>
<td><strong>Working memory - Digit Span Test</strong> WAIS III</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td><strong>Attention/Interference - Stroop Color Word Test</strong></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 WAIS III</td>
<td>Trained with AT. May improve with FM use</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)**

<table>
<thead>
<tr>
<th>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?</th>
<th>Comparing your ability now with your ability before this study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Much worse</td>
</tr>
<tr>
<td></td>
<td>-5</td>
</tr>
<tr>
<td>Not applicable</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>You are talking with one other person in a quiet, carpeted lounge-room. Can you follow what the other person says?</th>
<th>Comparing your ability now with your ability before this study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Much worse</td>
</tr>
<tr>
<td></td>
<td>-5</td>
</tr>
<tr>
<td>Not applicable</td>
<td></td>
</tr>
</tbody>
</table>
Cognitive Self Report Questionnaire (CSRQ)

- A 64-item questionnaire assessing daily functioning on 8 subscales:
## Cognitive Self Report Questionnaire (CSRQ)

<table>
<thead>
<tr>
<th>Question</th>
<th>Better</th>
<th>Same as before</th>
<th>Worse</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 than one thing at a time is...</td>
<td>Better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My ability to remember phone numbers is...</td>
<td>Better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My ability to hear things clearly is ...</td>
<td>Better</td>
<td></td>
<td></td>
<td></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.

* 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>
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

Competing sentences

Different voice Different location: TOTAL ADVANTAGE
Same 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)

ATTR – Gap detection

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

**Within channel**
- < normal: 56%
- ≥ normal: 42%

**Across channel**
- < normal: 57%
- ≥ normal: 43%

Other measures

HINT

% participants

< normal

52%

≥ normal

48%

Digital Span total score

≥ normal

Digit Span total score

< normal

Stroop interference
Results

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

<table>
<thead>
<tr>
<th>Percentage of Auditory Training Completed</th>
<th>% Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25%</td>
<td>70</td>
</tr>
<tr>
<td>25-49%</td>
<td>10-19 sessions</td>
</tr>
<tr>
<td>50-74%</td>
<td>20-29 sessions</td>
</tr>
<tr>
<td>75-100%</td>
<td>30-40 sessions</td>
</tr>
</tbody>
</table>

n= 37
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, partial eta squared = 0.025

Better

Benefit [digits]

-0.5 0.0 0.5 1.0 1.5 2.0

Forward Backward

FM + AT FM AT Control
F = 0.789, p = 0.504

Better

Benefit (Total errors)

FM+AT   FM     AT     Control
Significant differences across treatment arms for all scales except energy & satisfaction

- Better

- Benefit [Range: -8 to +8]

- Ctl, FM

- * FM + AT

- FM

- AT

- Control

- Attention

- Executive function

- Language

- Vision

- Hearing

- Energy

- Satisfaction
PIADS

Better [Range: -3 to +3]

-0.5
0.0
0.5
1.0
1.5

Competence  Adaptability  Self-esteem

<table>
<thead>
<tr>
<th></th>
<th>FM + AT</th>
<th>FM</th>
<th>AT</th>
<th>Control</th>
</tr>
</thead>
</table>

- Benefit range from -3 to +3
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
A Quick plug for ....

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

Beyond the Audiology Clinic: Innovations and Possibilities of Connected Health

Elizabeth Krupinski, Ph.D. (Keynote)
Harvey Abrams, Ph.D.
Deborah Ferrari, Ph.D.
Jeffrey Kaye, Ph.D.
Robert Margolis, Ph.D.
Chad Galdden, Au.D.

Terry Chisolm, Ph.D.
Louise Hickson, Ph.D.
John Kokesh, M.D.
Jerry Northern Ph.D.
Beyond the Audiology Clinic: Innovations and Possibilities of Connected Health

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

Explosion → Solid/liquid is converted into highly pressurized gas

Peak Overpressure (shock wave)

Highly pressurized gas expands →

Shock wave travels through air rapidly expanding resulting in

Negative underpressure

Secondary Overpressure

Behind vacuum air rushes in = blast wind occurs
Evaluation of Approaches to Auditory Rehabilitation for mTBI

Research Team:

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Paula Myers
Melissa Teahen,
Michelle Arnold
ShienPei Silverman

Study funded by VA RR&D grant #: C7054R
HINT – Performance and Perceptual

![Graph showing benefit in dB SNR for different conditions: Performance SRTN and Perceptual SRTN. The graph compares FM + AT, FM, AT, and Control groups. There is a significant difference marked with an asterisk (*) between the FM + AT and FM groups in the Performance SRTN category.]
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
## Test protocol

<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
Performance test data

Abnormal score (% participants)

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

Participants (%)

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

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

Controls

Blast Exposed

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