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

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VA RR&D 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)**

Owens et al (2008) J Trauma., 64(2): 295-99

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**

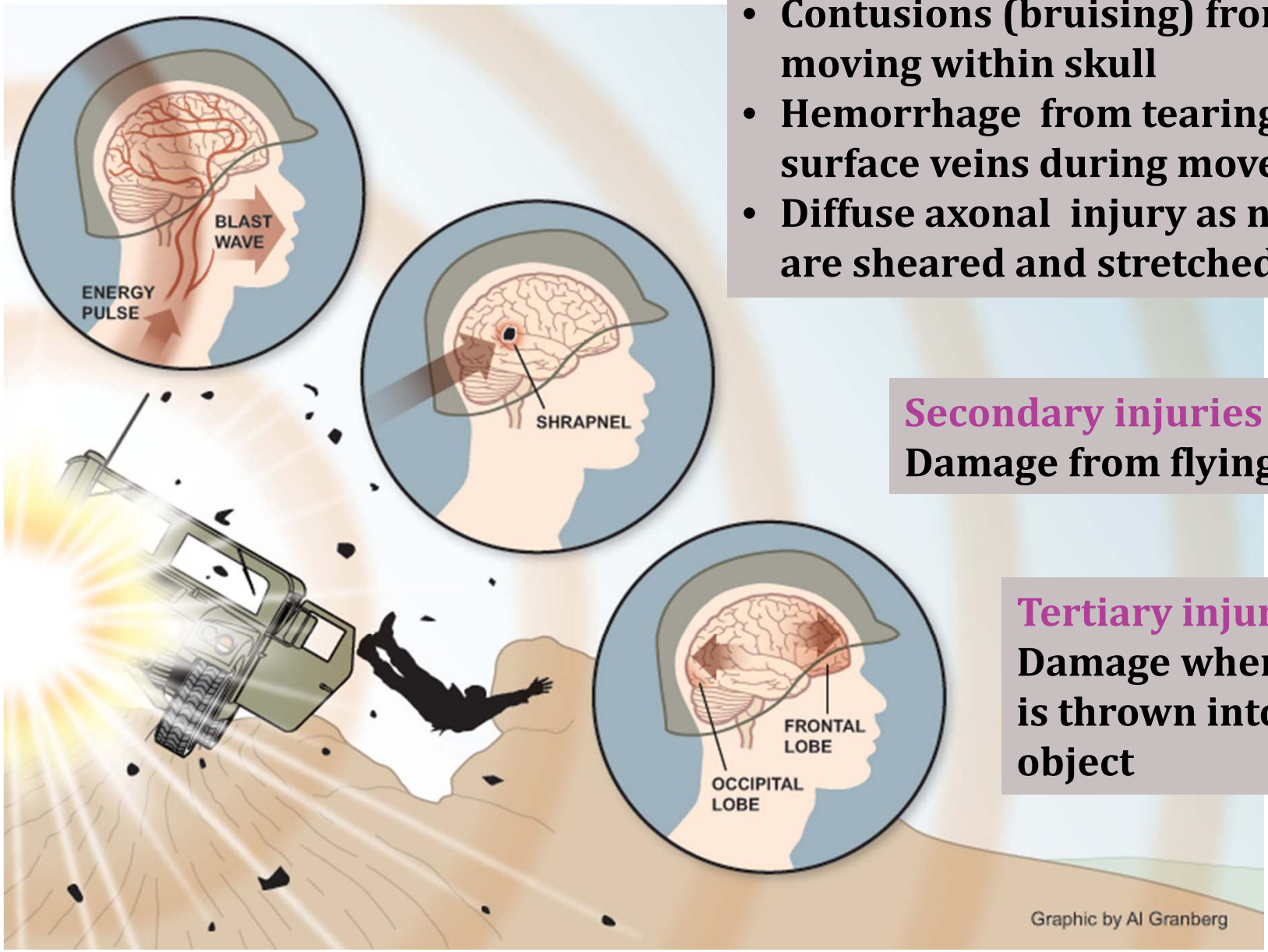
Saunders & Echt (2012), JRRD, 49(7): 1043-1058 2012

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

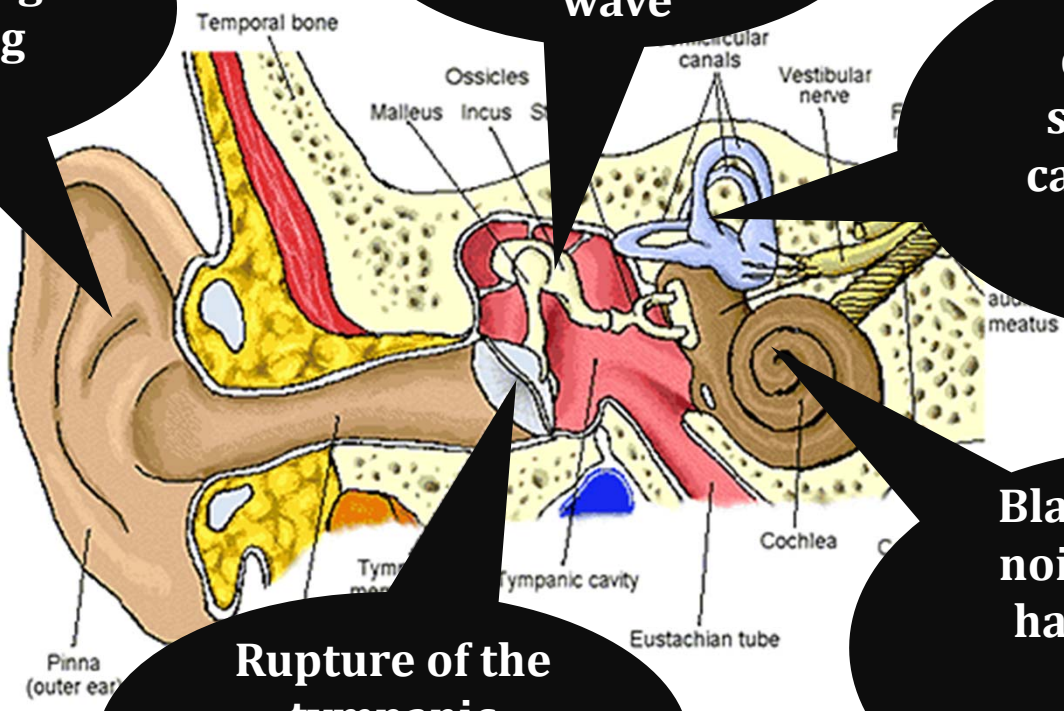
Blast damage to the auditory system

Peripheral Damage

Pinna damage: burns/damage from flying debris

Ossicular disruption from pressure wave

Blast wave damages to semicircular canals causing vestibular problems



Rupture of the tympanic membrane from pressure wave

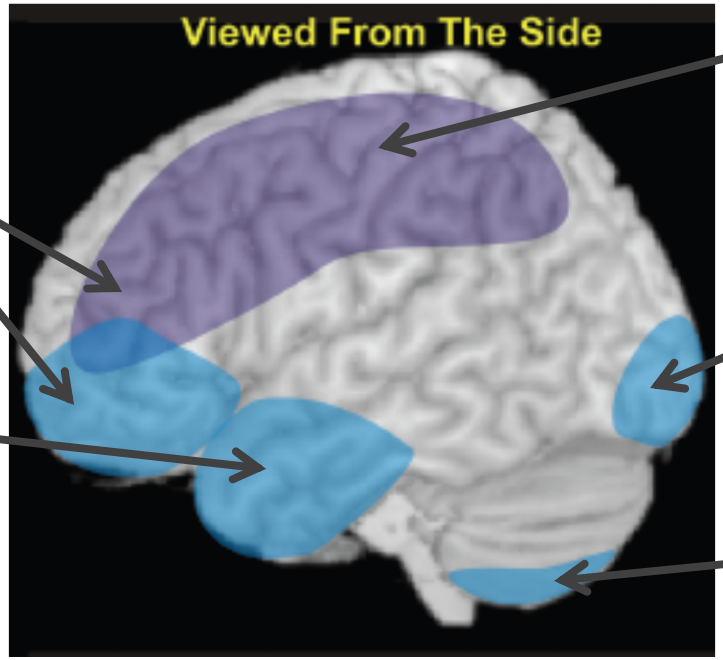
Blast wave and noise damages hair cells and basilar membrane in cochlea

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

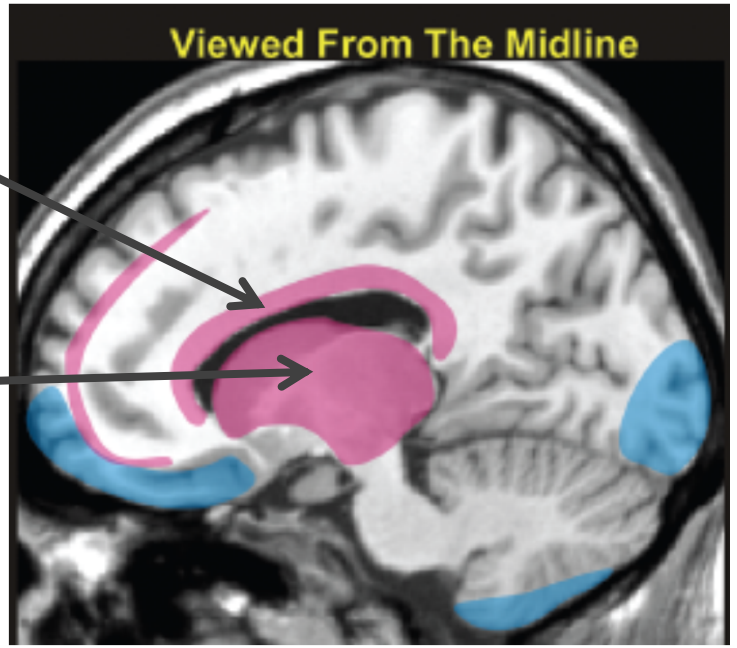
Cerebellum
Balance

Taber et al (2006) . J Neuropsychiatry Clin Neurosci. 18(2):141-45.

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

Taber et al (2006) . J Neuropsychiatry Clin Neurosci. 18(2):141-45.

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** — **Signal-to-noise ratio (SNR)**
- **Following rapid speech** — **Temporal processing**
- **Following instructions and long conversations** — **Working memory**
- **Tinnitus**
- **Hyperacusis**

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

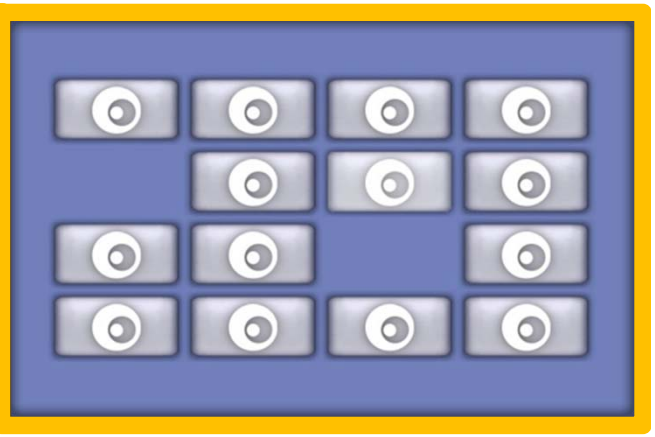
  40 sessions, 60 min/day

The Brain Fitness Program: Training Tasks

- **High or Low?**

- **Tell Us Apart**

- **Match It!**



- **Sound Replay**

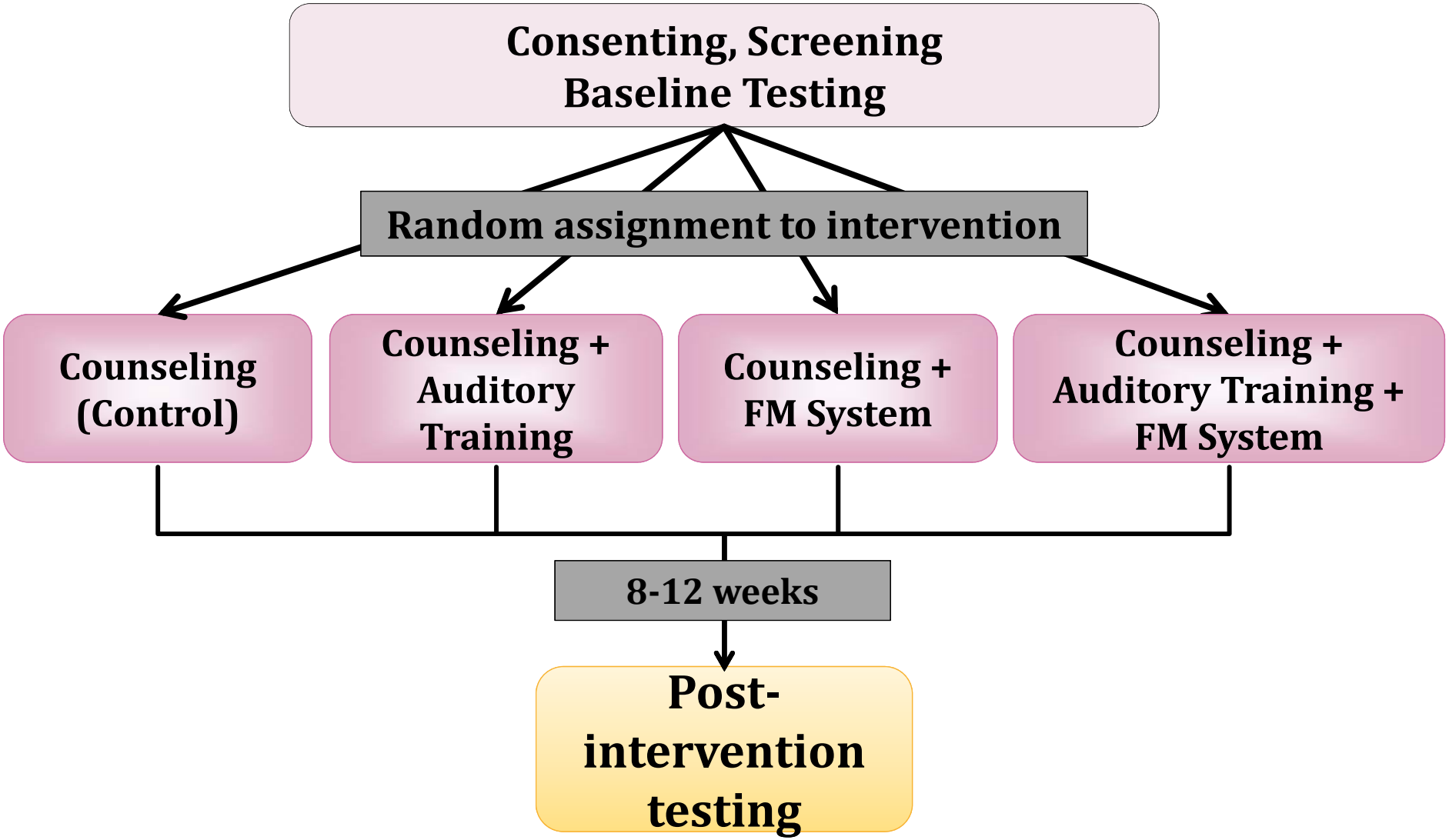
- **Listen and Do**

- **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



Outcome Measures: Performance

Test measure	Rationale for Testing
Gap detection - Adaptive Tests of Temporal Resolution ATTR	
Time Compressed Speech	
Working memory - Digit Span Test WAIS III	
Dichotic - Staggered Spondaic Word test (SSW)	

Staggered Spondaic Word Test (SSW)

Fruit
Juice

Cup
Cake

Four Test Conditions:

Right non-competing (RNC)

Right competing (RC)

Left competing (LC)

Left non-competing (LNC)

Outcome Measures: Performance

Test measure	Rationale for Testing
Gap detection - Adaptive Tests of Temporal Resolution ATTR	
Time Compressed Speech	
Working memory - Digit Span Test WAIS III	
Dichotic - Staggered Spondaic Word test (SSW)	
Attention/Interference - Stroop Color Word Test	

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

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

Self-Report Outcome Measures

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

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.**

Gatehouse & Noble (2004) Int. J. Audiol 43(2):85-99

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** ***Much worse*** ***Unchanged*** ***Much better*** **Not applicable** ☐ **-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5**
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** ***Much worse*** ***Unchanged*** ***Much better*** **Not applicable** ☐ **-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5**

Cognitive Self Report Questionnaire (CSRQ)

- **A 64-item questionnaire assessing daily functioning on 8 subscales:**

  Attention, Executive function, Memory, Language, Vision, Hearing, Energy, Satisfaction.

Cognitive Self Report Questionnaire (CSRQ)

I lose my train of thought…	Less often	Same as before	More often	Does not apply
My ability to pay attention to more than one thing at a time is…	Better	Same as before	Worse	Does not apply
My ability to remember phone numbers is…	Better	Same as before	Worse	Does not apply
My ability to hear things clearly is ….	Better	Same as before	Worse	Does not apply

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

PIADS

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)

	Decreases			No change		Increases	
	-3	-2	-1	0	1	2	3
Competence							
Happiness							
Adequacy							
Confusion							
Self-esteem							
Productivity							
Usefulness							
Well-being							

Results

Data collected from 86 participants.

	FM+AT	AT	FM	Control
n	22	15	24	25
Age	33.1	34.8	33.9	33.7
4F-PTA	13.4	11.0	12.1	12.1
Gender	Male: 22 Female: 0	Male: 12 Female:3	Male: 19 Female: 5	Male: 22 Female:3

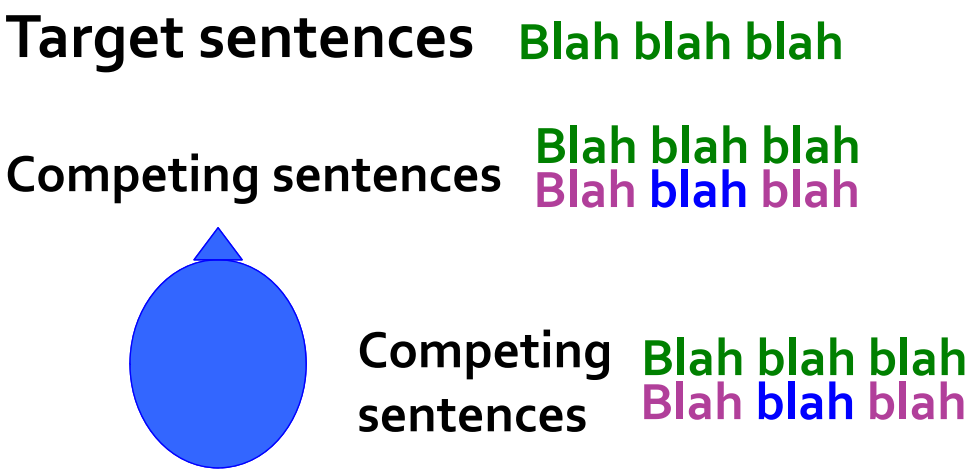
Baseline Performance

- **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



Same voice Different location: SPATIAL ADVANTAGE

Different voice Same location: TALKER ADVANTAGE

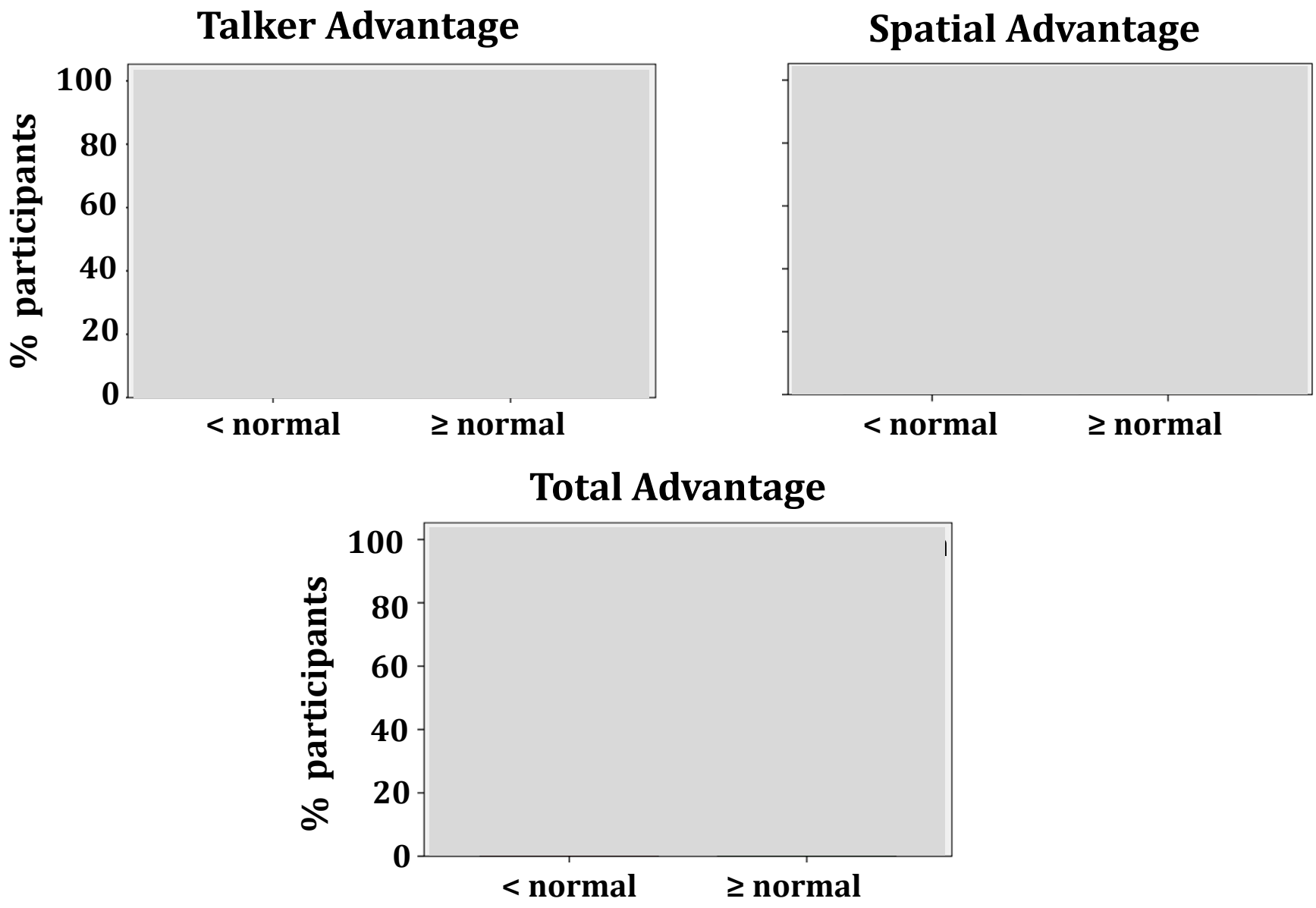
Different voice Different location: TOTAL ADVANTAGE

Listening in spatialized noise-sentences test (LISN-S)

Normative data from Cameron et al (2011)

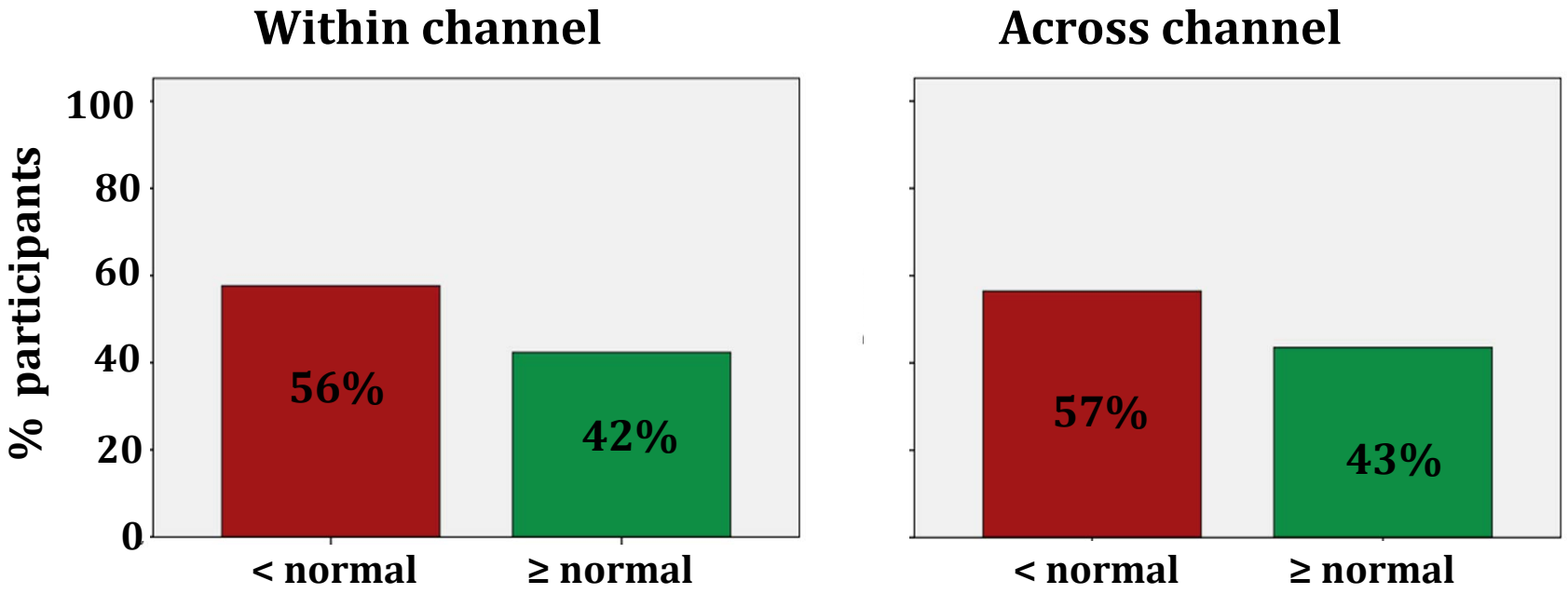
Cameron et al (2011) J Am Acad Audiol 22:697-709

LISN-S


Talker Advantage
% participants
100
80
60
40
20
0
< normal
≥ normal
Spatial Advantage
< normal
≥ normal
Total Advantage
% participants
100
80
60
40
20
0
< normal
≥ normal

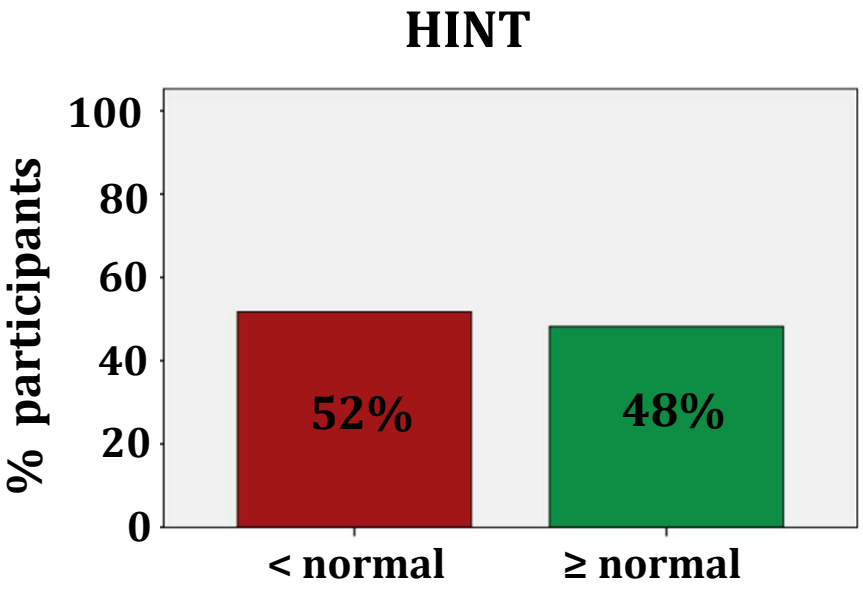
ATTR – Gap detection

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



Lister et al (2011) Int J Audiol, 50:367-374

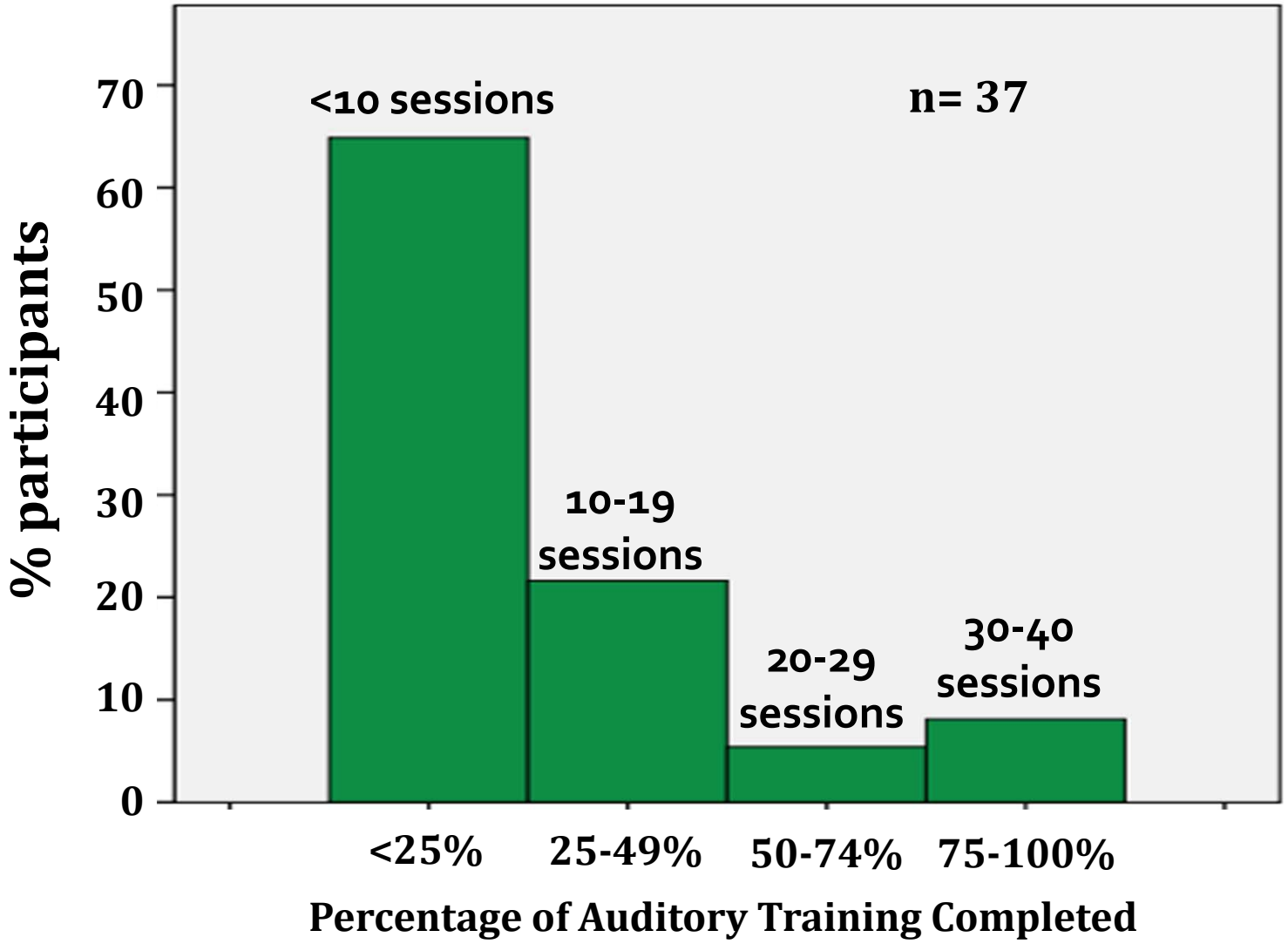
Other measures



Results

Did the participants use the interventions?

Compliance with intervention Auditory Training



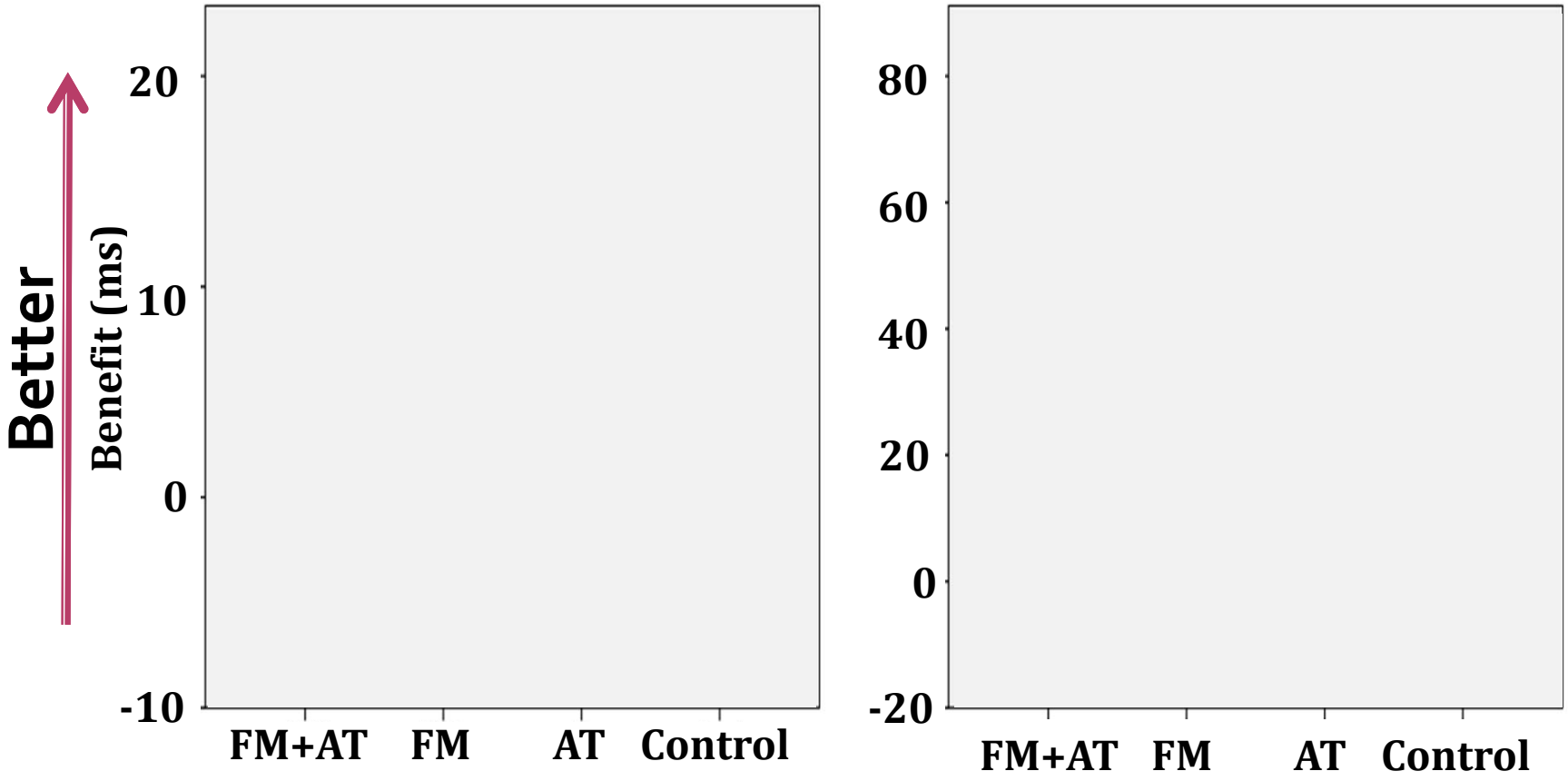
Compliance
FM System

- **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

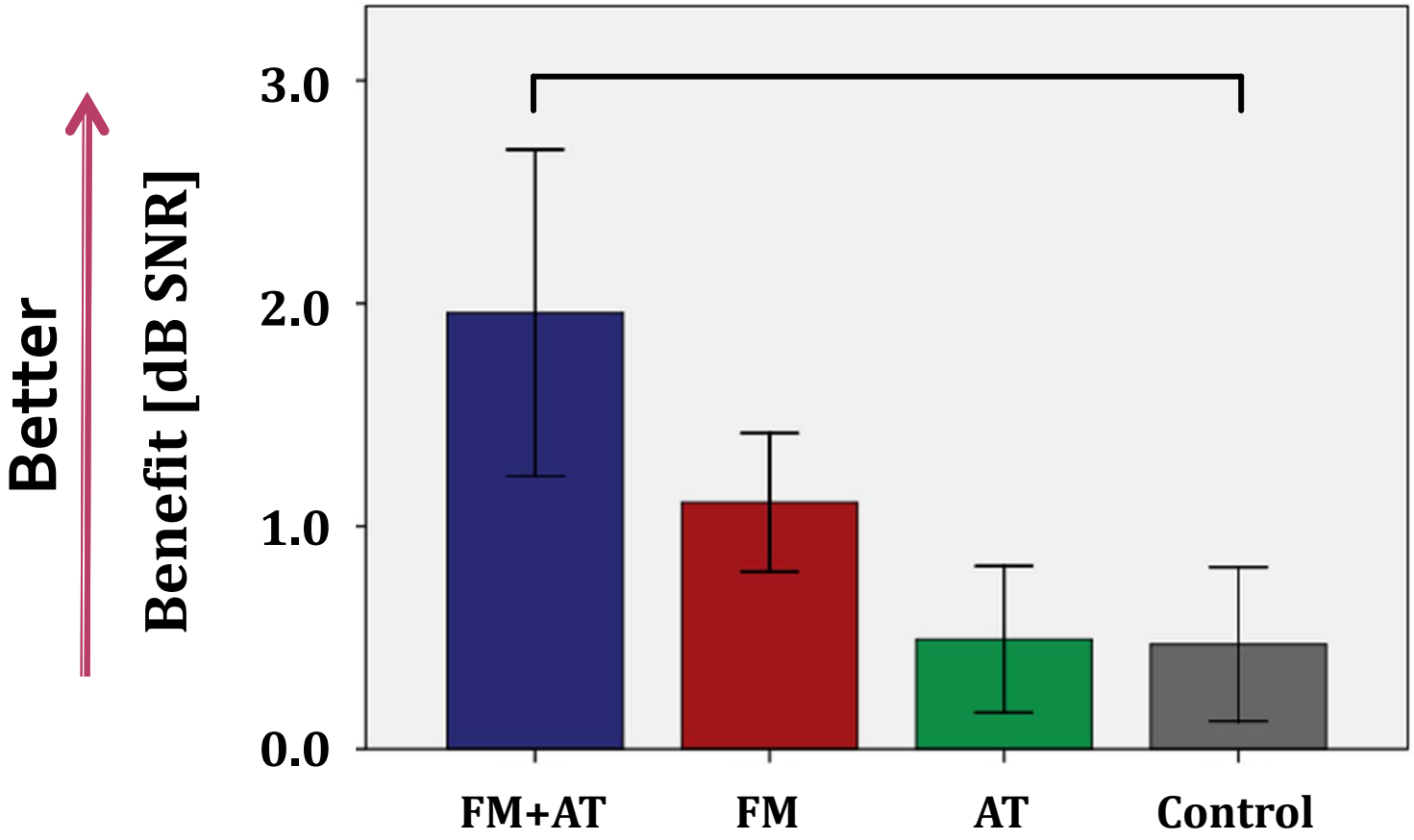
Gap detection - All subjects

F=2.19, p=0.096, partial eta squared = 0.075



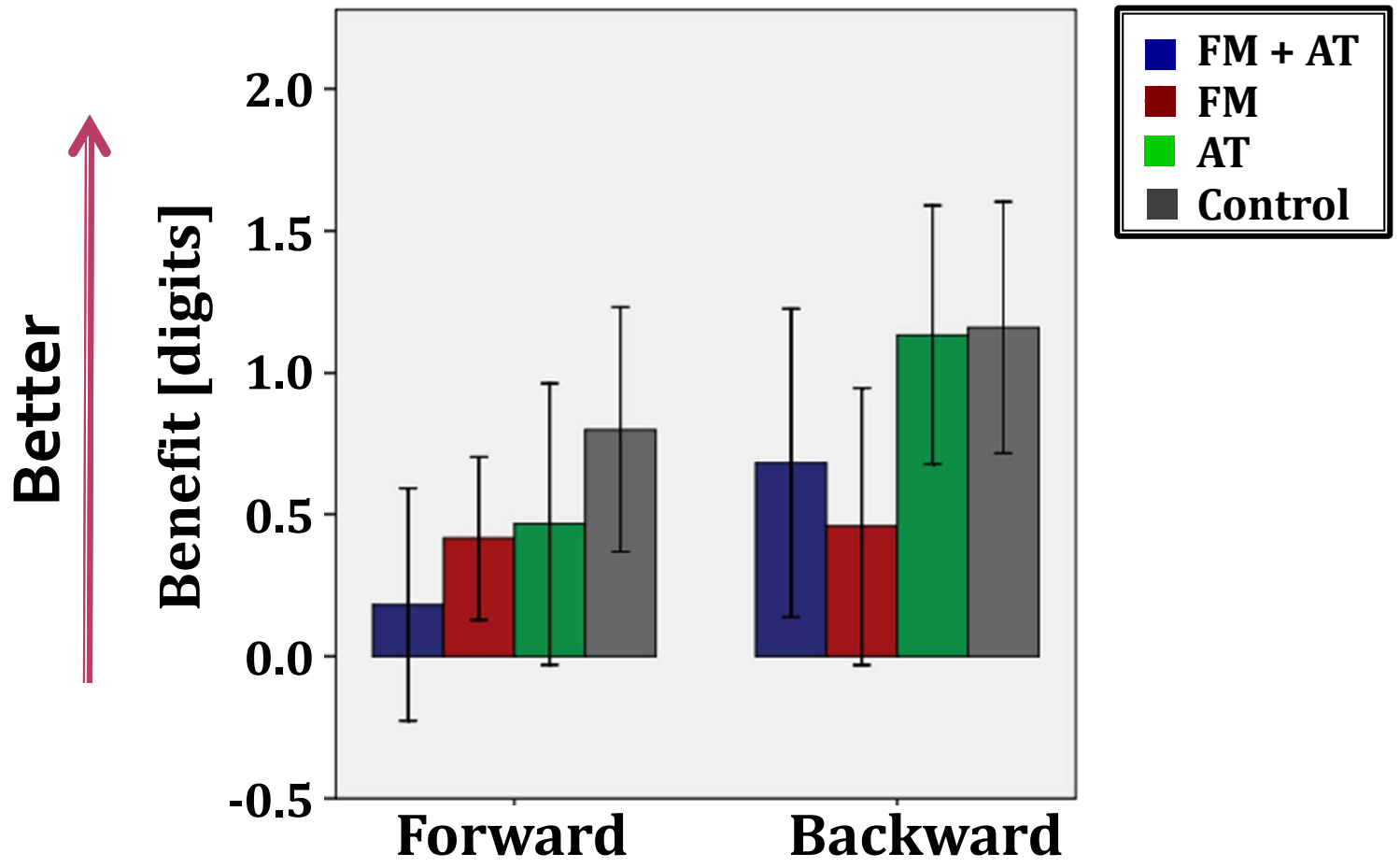
Speech-in-Noise - HINT

F=2.11, p=0.105, partial eta squared = 0.076

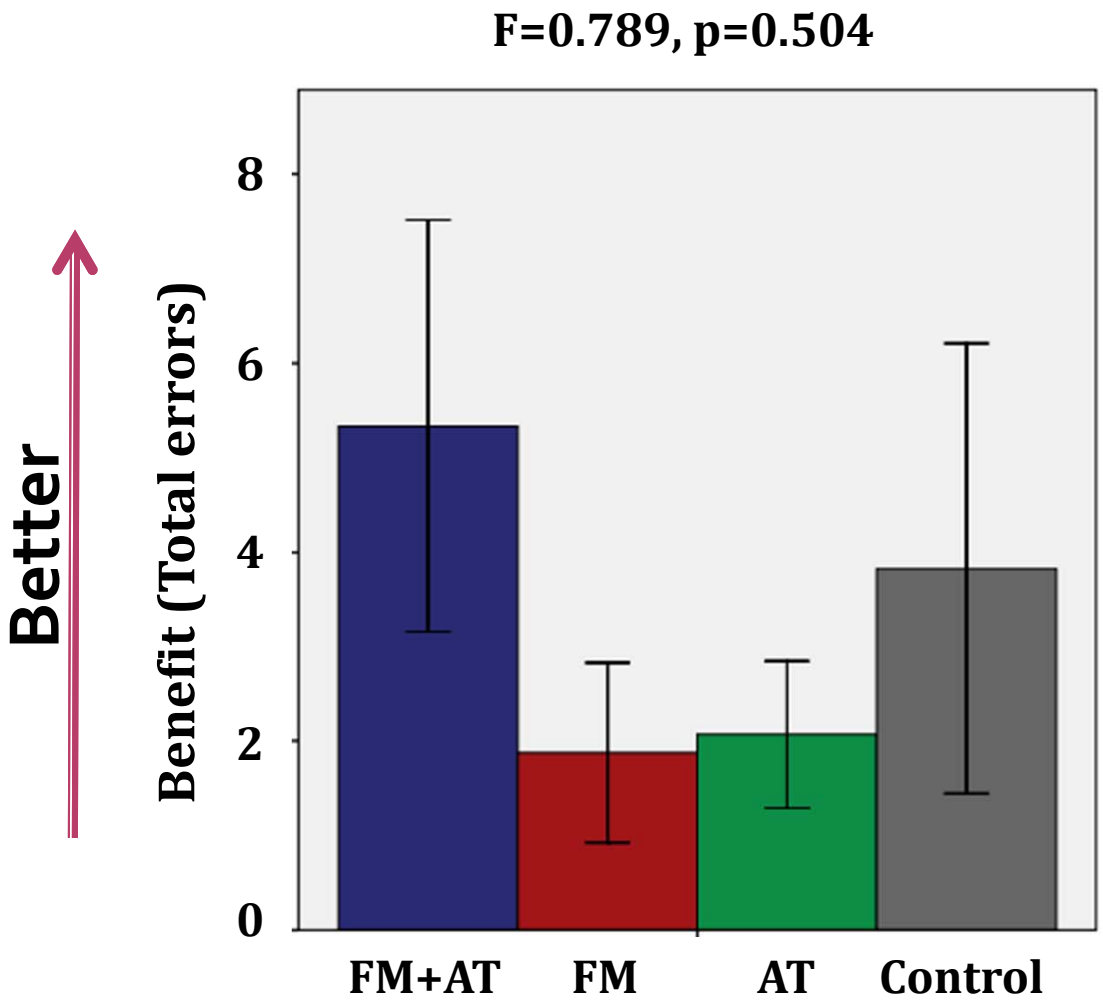


Digit Span

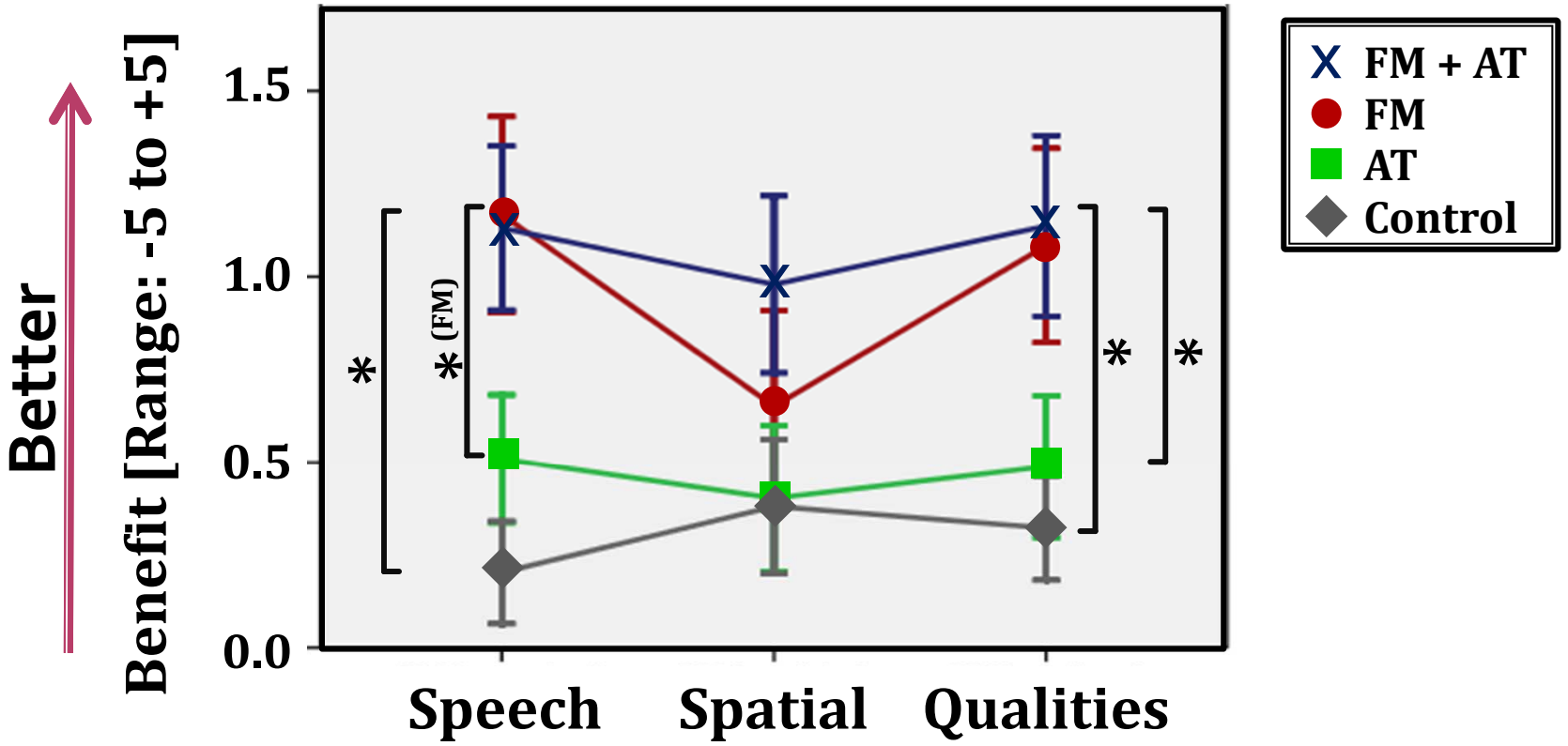
F=0.692, p=0.560, partial eta squared = 0.025



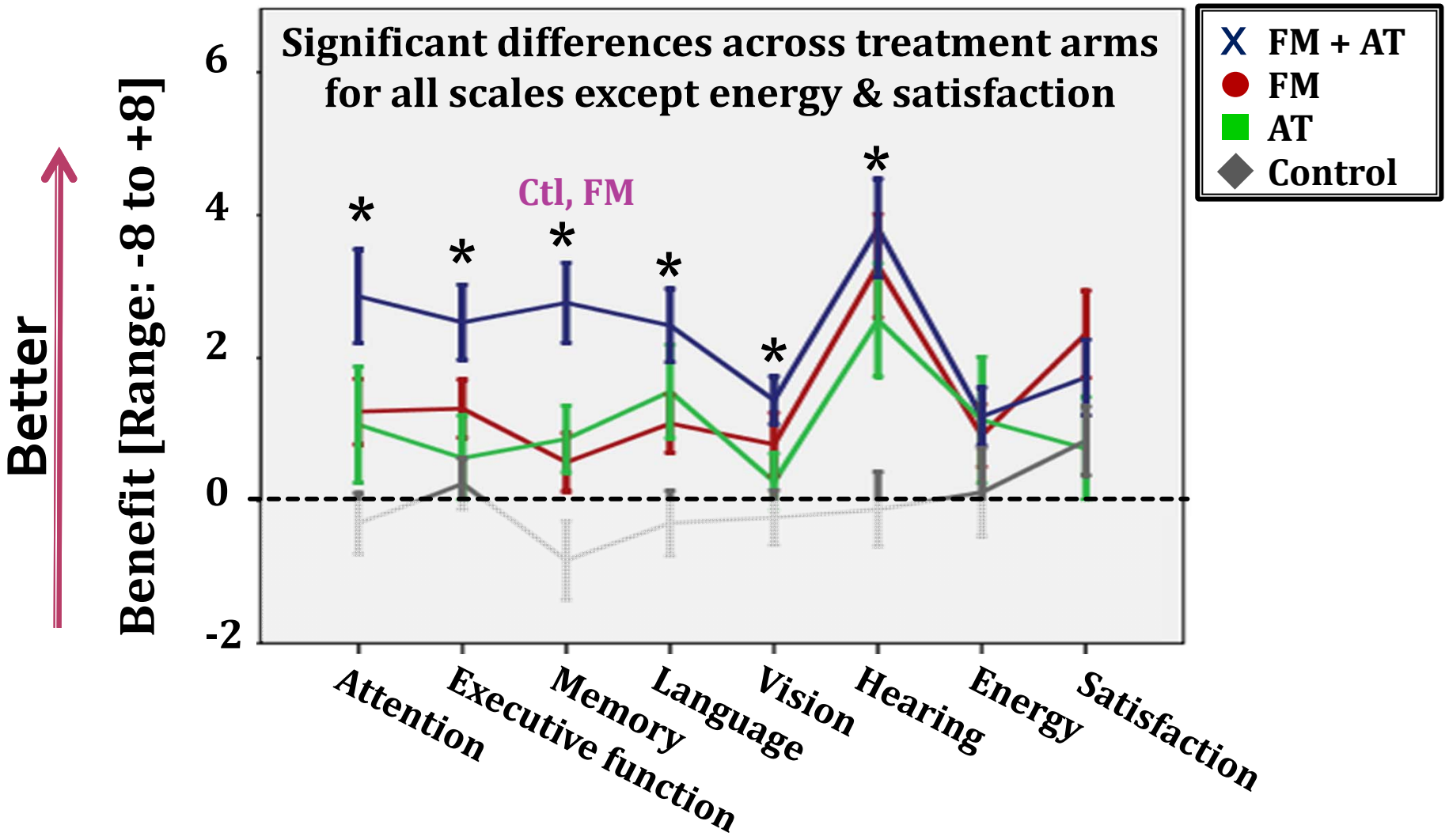
SSW


F=0.789, p=0.504
Better
Benefit (Total errors)
8
6
4
2
0
FM+AT
FM
AT
Control

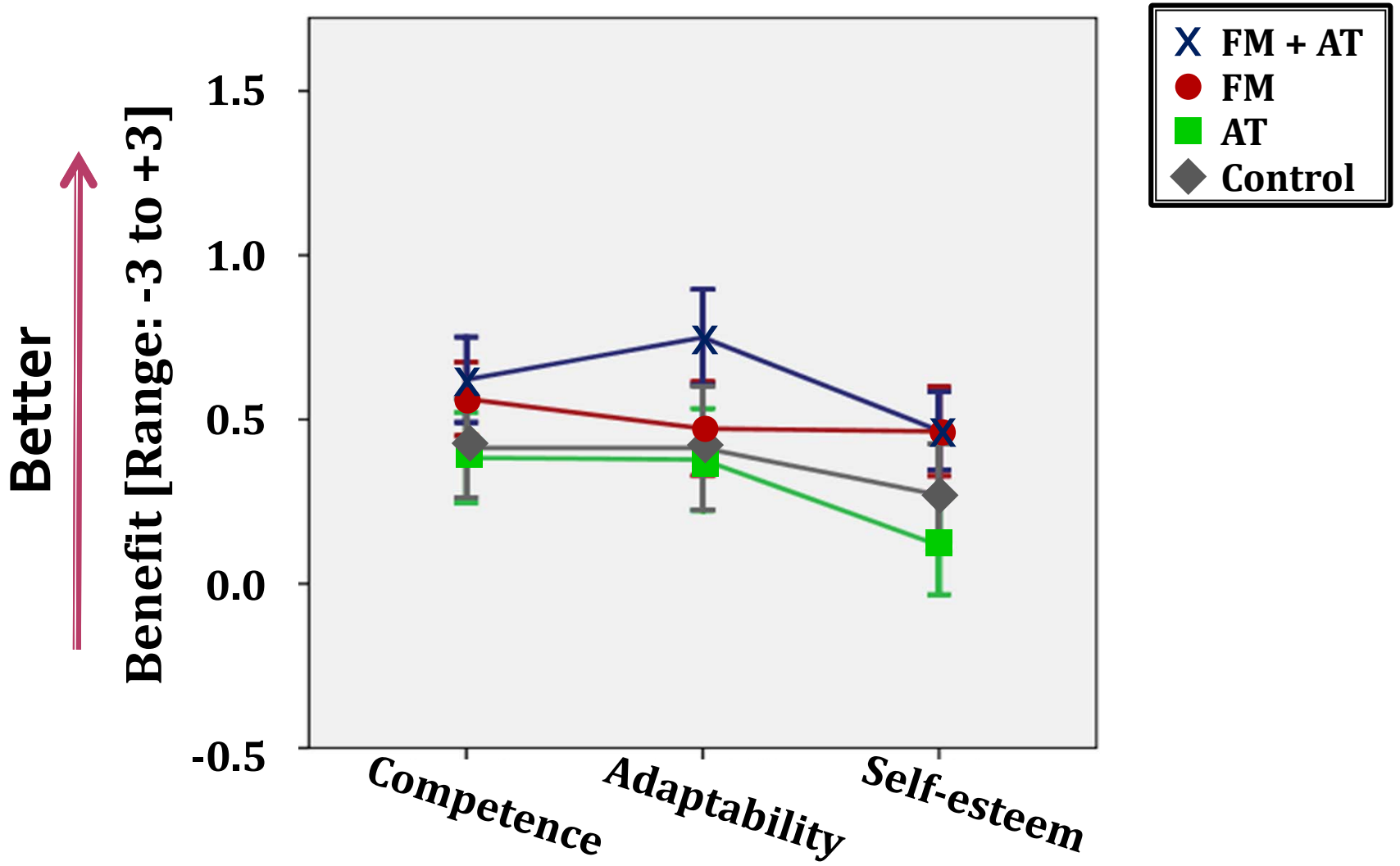
SSQ-C


Better
Benefit [Range: -5 to +5]
1.5
1.0
0.5
0.0
Speech
Spatial
Qualities
*
* (FM)
*
*
FM + AT
FM
AT
Control

CSRQ


Significant differences across treatment arms for all scales except energy & satisfaction
Ctl, FM
FM + AT
FM
AT
Control
Better
Benefit [Range: -8 to +8]
6
4
2
0
-2
*
Attention
Executive function
Memory
Language
Vision
Hearing
Energy
Satisfaction

PIADS


Better
Benefit [Range: -3 to +3]
1.5
1.0
0.5
0.0
-0.5
Competence
Adaptability
Self-esteem
FM + AT
FM
AT
Control

Summary

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

Summary (cont.)

- **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#

Format allows user to direct their own training

A Quick plug for ….

NCRAR Conference: September 18-20th 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

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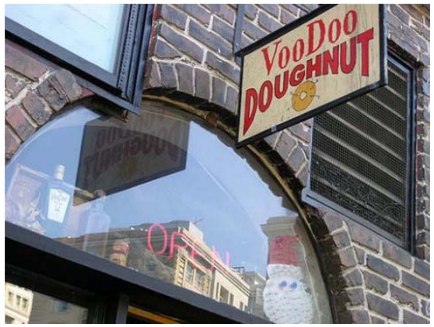
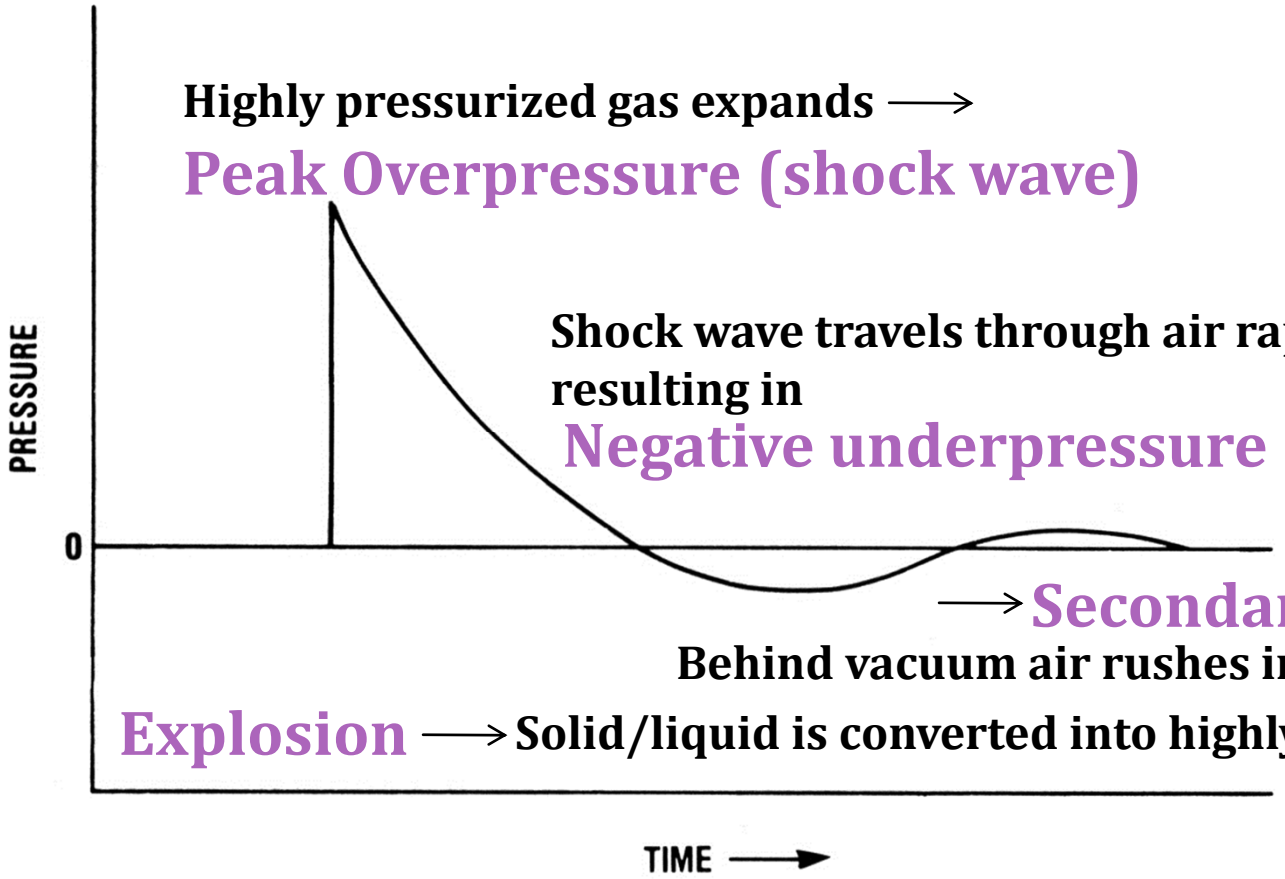


Blast wave physics



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

VA RR&D

NCRAR

Evaluation of Approaches to Auditory Rehabilitation for mTBI

Research Team:

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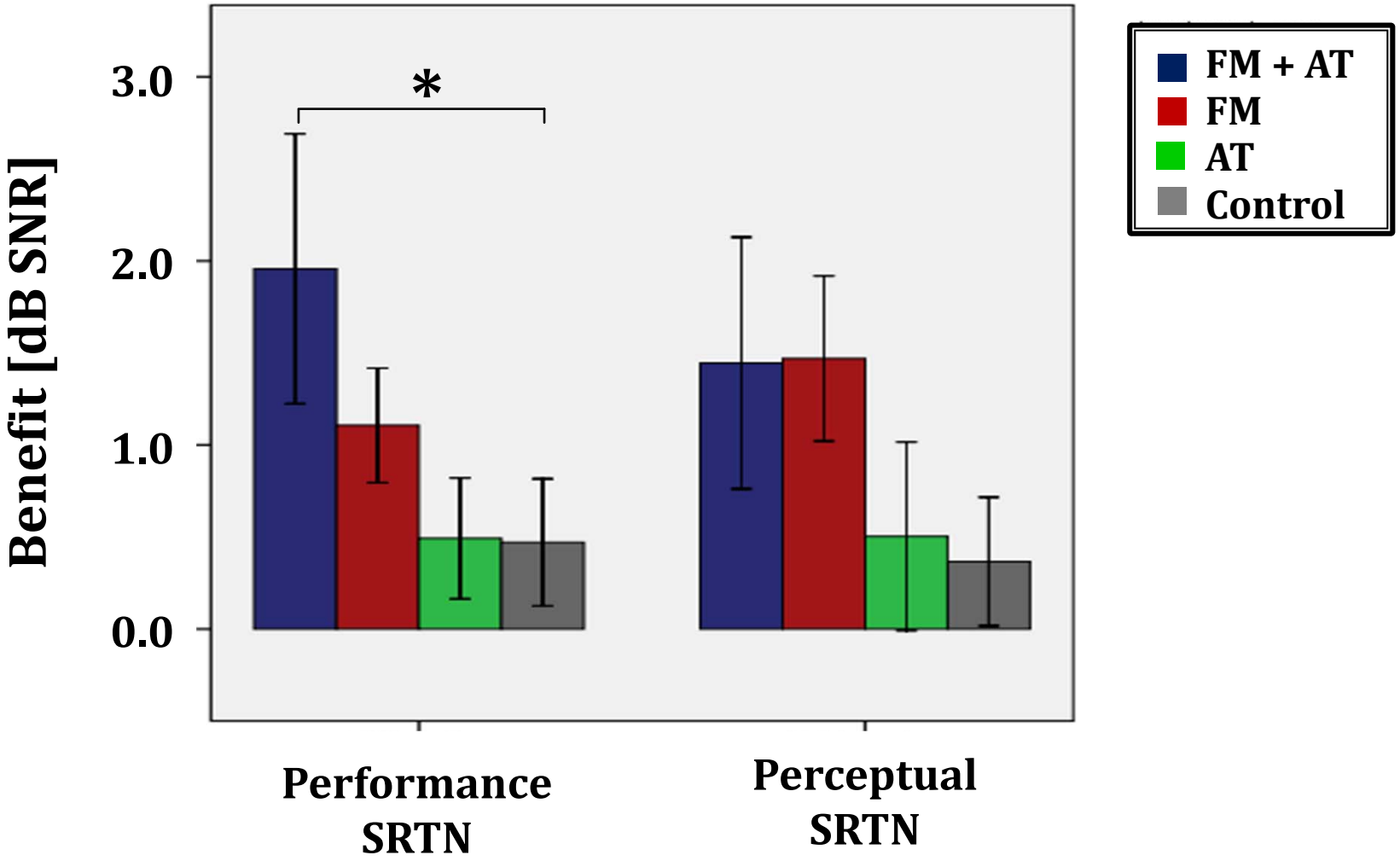
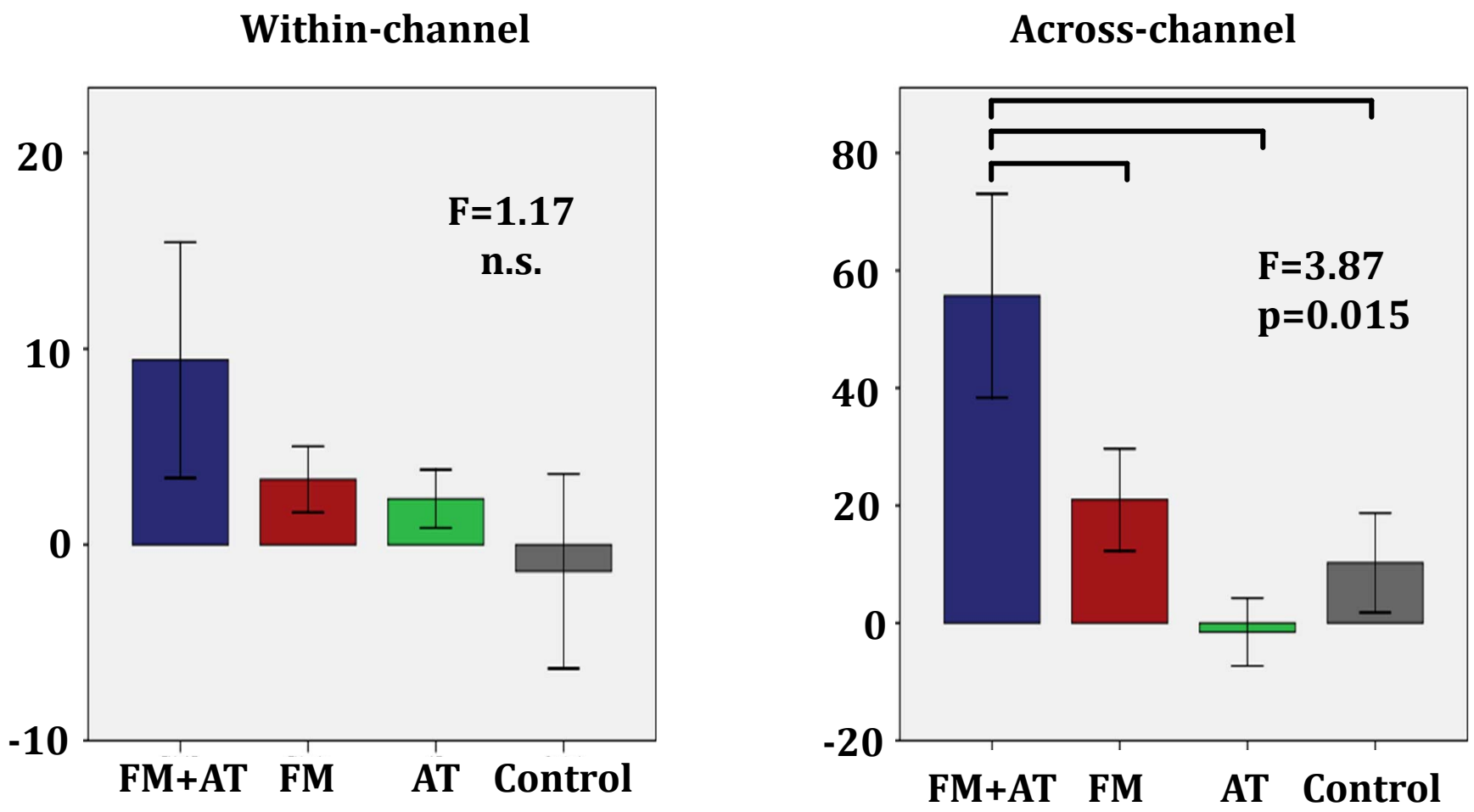
ShienPei Silverman

Study funded by VA RR&D grant #: C7054R

HINT – Performance and Perceptual



Gap detection – baseline performance below normal



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**

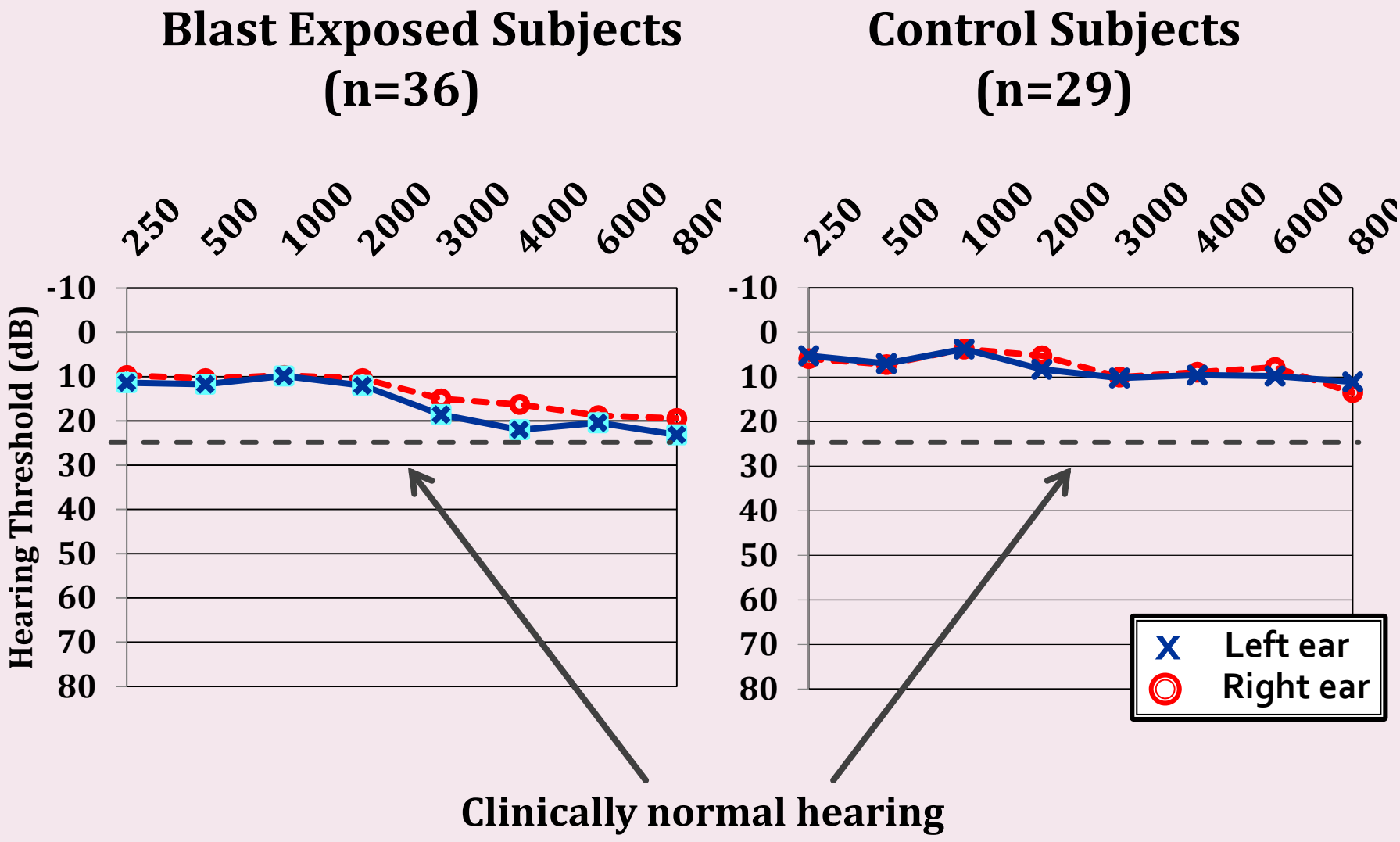
29 controls, matched to soldiers on age and hearing

- **Tested at NCRAR**
- **Non-blast exposed**
- **Mean Age: 33.4 years**

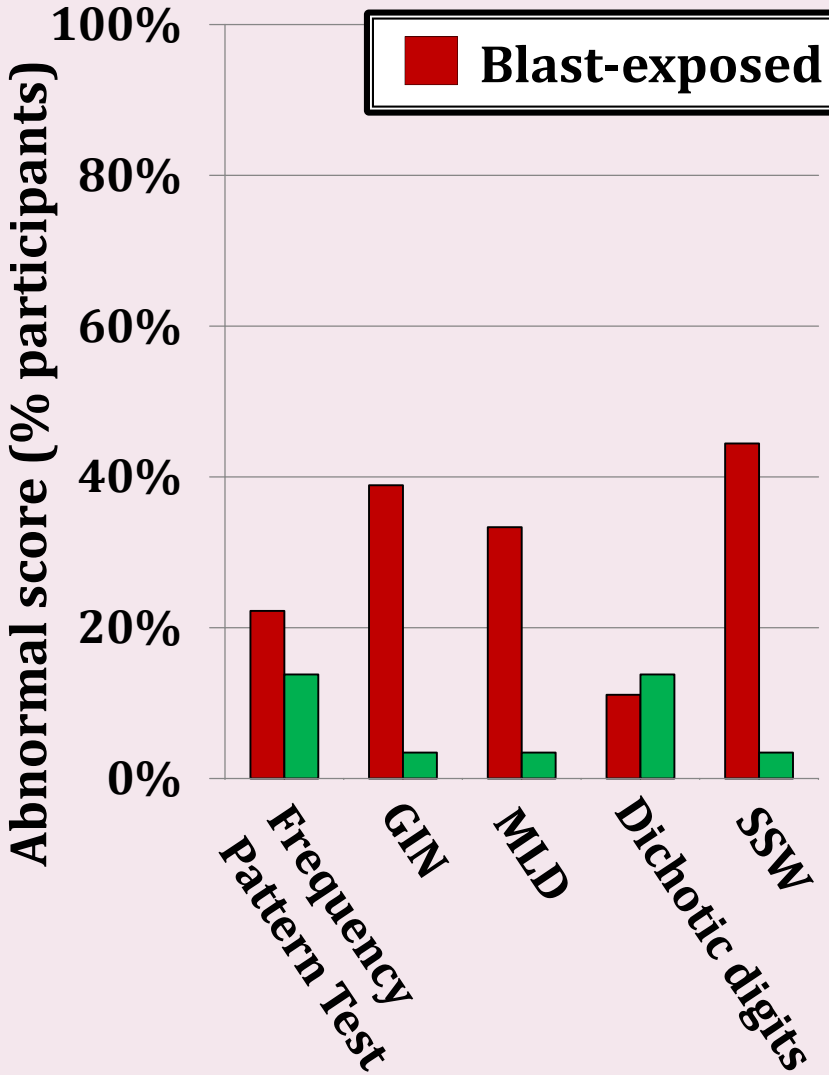
Test protocol

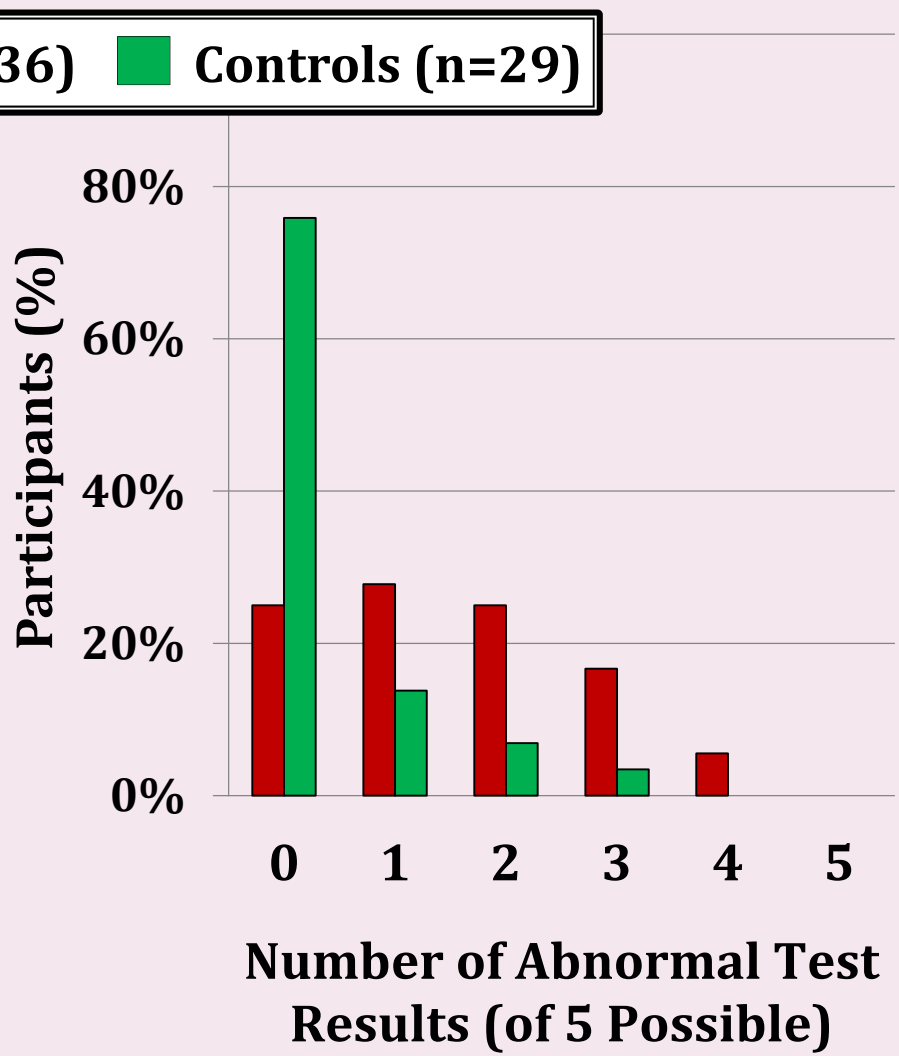
Test	Site of lesion
Audiometric evaluation	Sensorineural vs. conductive vs. none
Gaps in Noise (GIN)	Cortex; corpus callosum
Staggered Spondaic Word Test (SSW)	Cortex; corpus callosum
Masking Level Difference (MLD)	Brainstem
Frequency Pattern Test (FPT)	Cortex; corpus callosum; brainstem
Dichotic Digits Test (DDT)	Cortex; corpus callosum
Auditory Brainstem Response Waves I to VII	Auditory nerve to auditory cortex
Long-latency responses (N1, P2, P3)	Auditory cortex

Audiometric data



Performance test data





Long-Latency Potentials