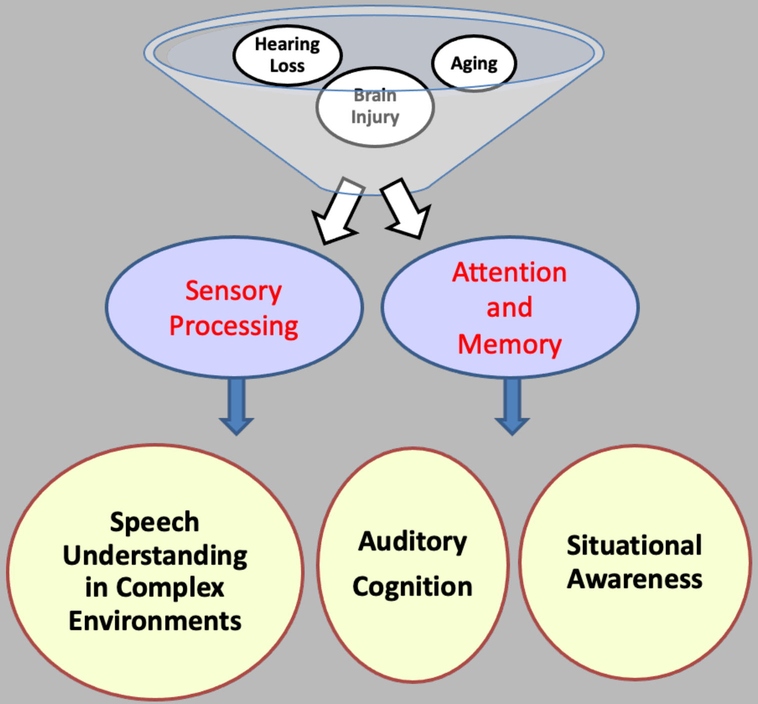
Assessment and Training of The Ability to Make Sense of Sound



Frederick (Erick) Gallun, PhD

Professor
Dept. of Otolaryngology
Oregon Hearing Research Center
Neuroscience Graduate Program
Oregon Health and Science University

This research was supported by

National Institutes of Health

R01 DC 011828

R01 DC 015051

R03 HD 094234

and

Dept. of Veterans Affairs

Rehabilitation Research and Development

NIDCD

National Institute on Deafness and Other Communication Disorders

Eunice Kennedy Shriver NICHD

National Institute of Child Health & Human Development

DEPARTMENT OF VETERANS AFFAIRS

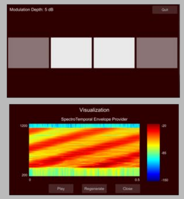
UNITED STATES OF AMERICA

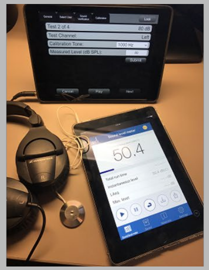
Overview

1. Making Sense of Sound

2. Portable Automated Rapid Testing (PART)

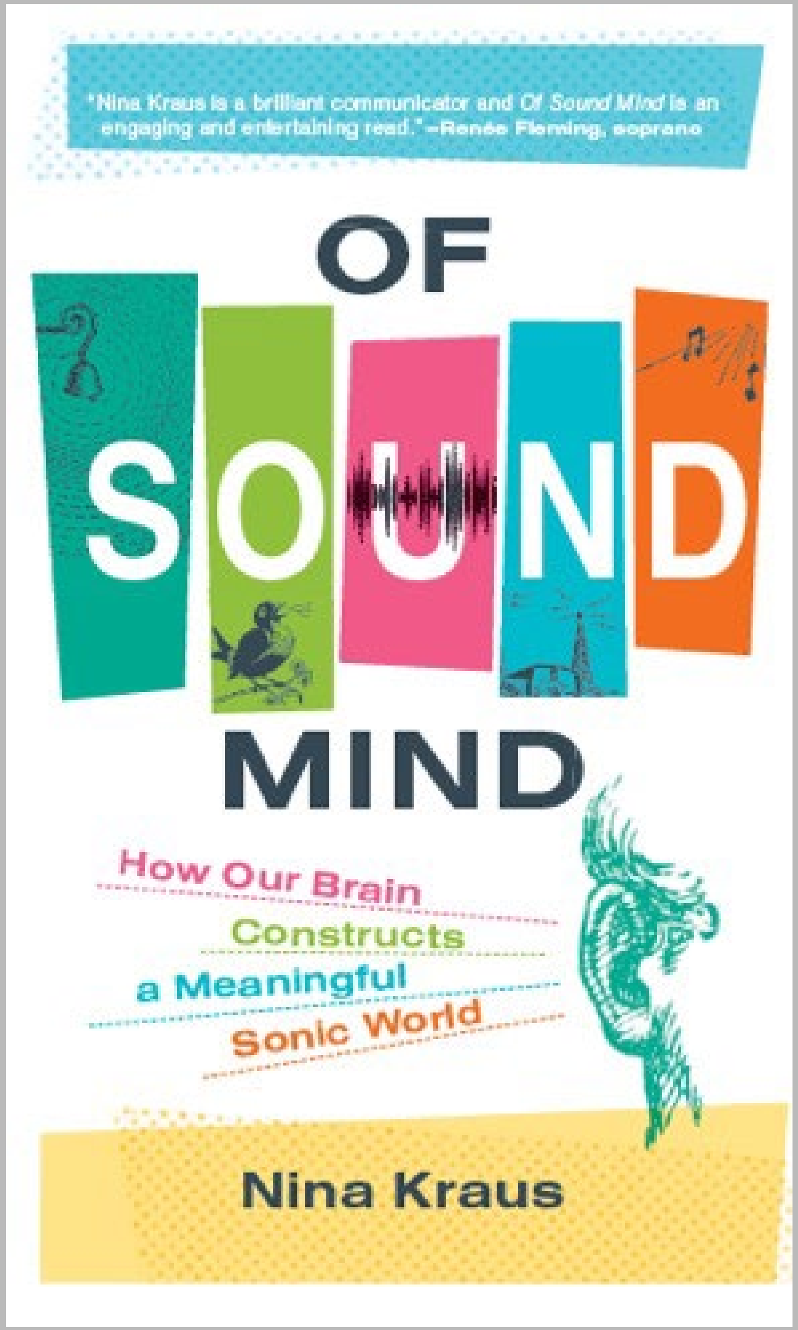
3. Listen: An Auditory Training Experience



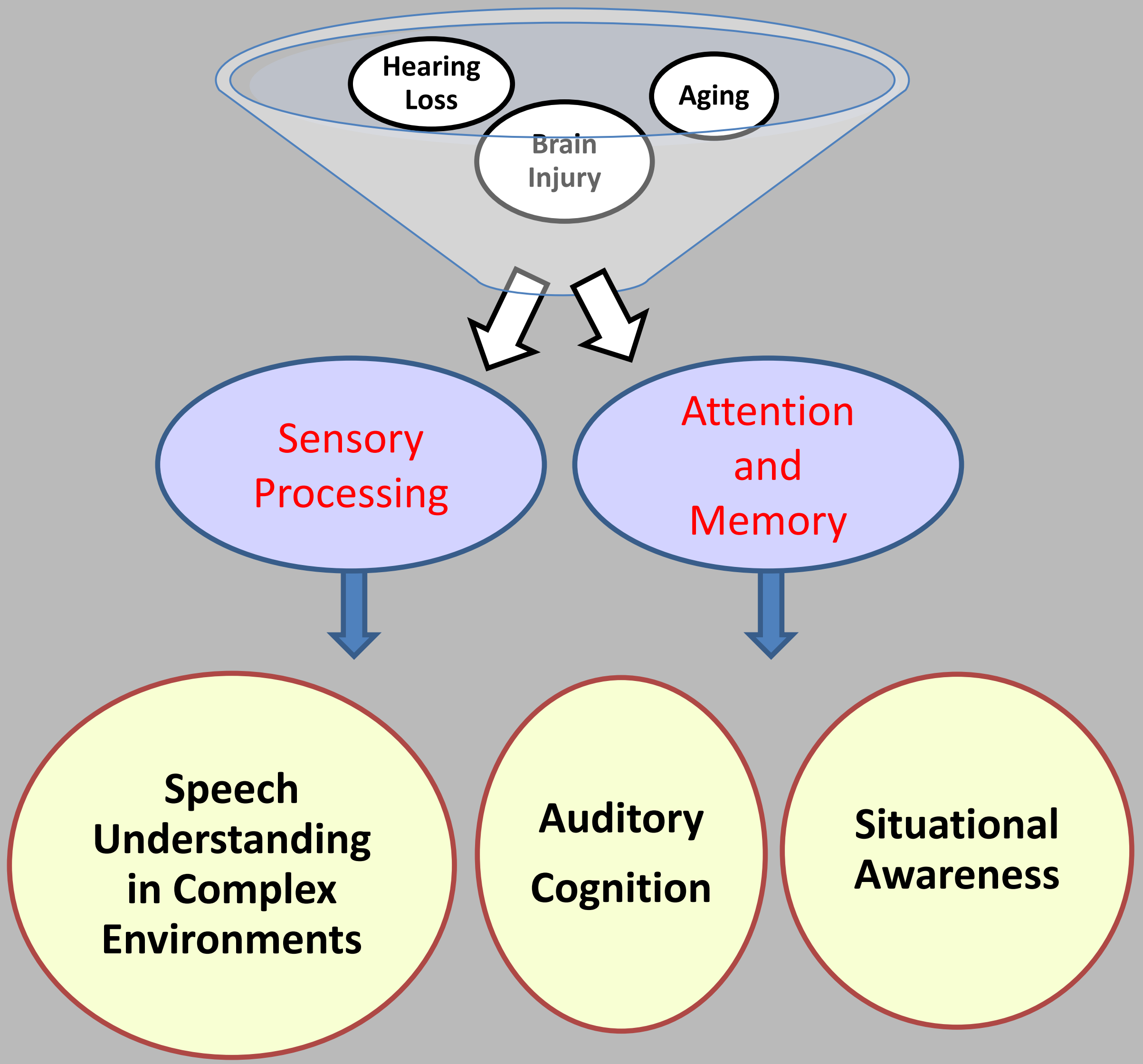


PART 1

Making Sense of Sound



Making Sense of Sound



Blast Exposure and Traumatic Brain Injury (TBI)

One of the most common effects of blast exposure is mild TBI, also known as concussion.

Table 8. Sensory and pain symptom scales.

Characteristic	Study group: TBI (N = 414)	Study group: No TBI (N = 78)	Adjusted p-value[a]
Hearing handicap index (HHI)[w]			
No hearing problems lately	194 (47.8%)	60 (76.9%)	0.0005
No handicap	50 (12.3%)	4 (5.1%)	.
Mild-moderate handicap	104 (25.6%)	12 (15.4%)	.
Severe handicap	58 (14.3%)	2 (2.6%)	.

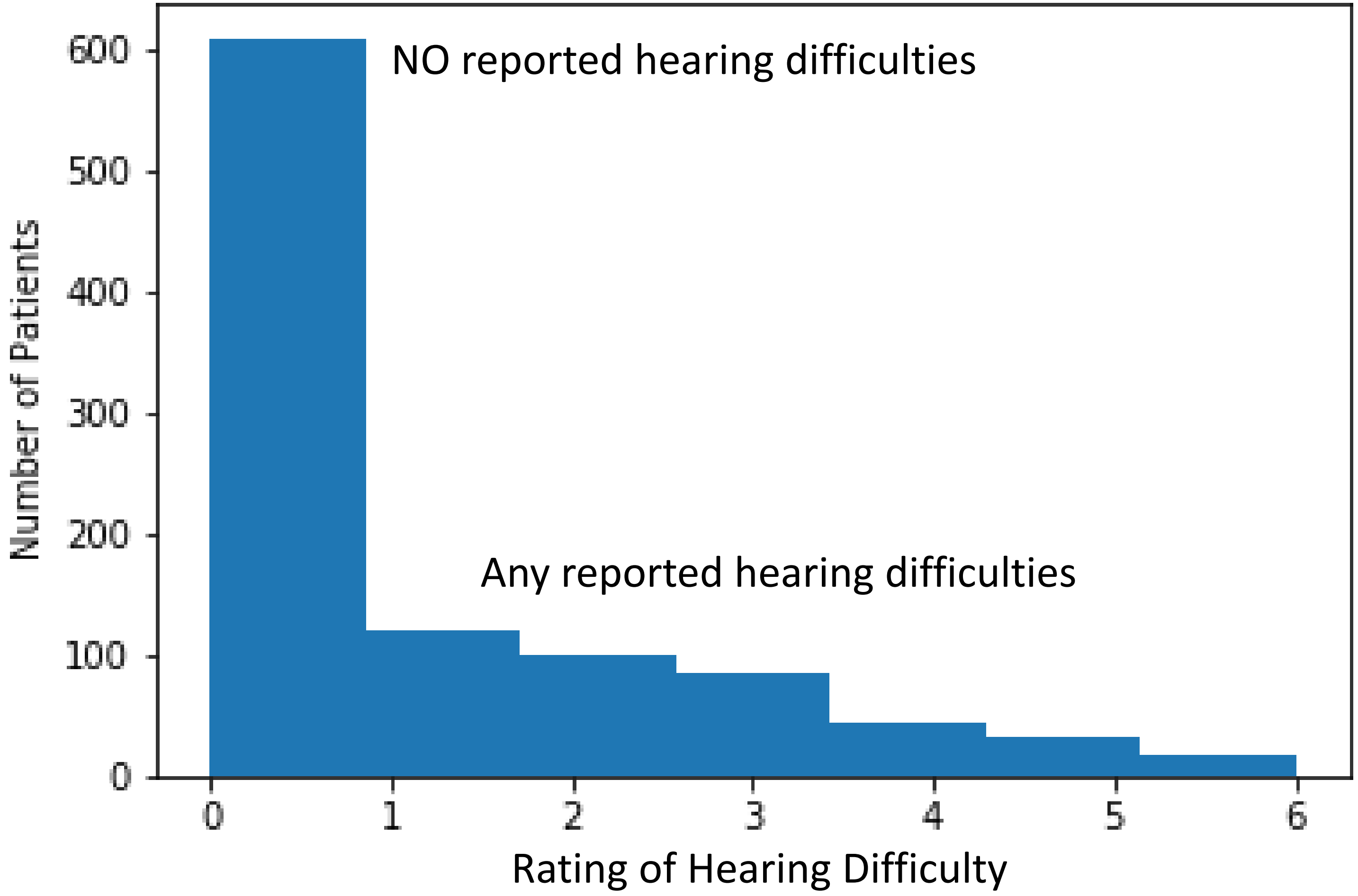
52% of blast-exposed report hearing problems
23% of control group report hearing problems

Walker et al. (2018) "Chronic Effects of Neurotrauma Consortium (CENC) multicentre study interim analysis: Differences between participants with positive versus negative mild TBI histories", *Brain Injury*, 32:9, 1079-1089

1000 non-Blast mild TBI Patients Seen by OHSU Concussion Clinic (2016-2018)

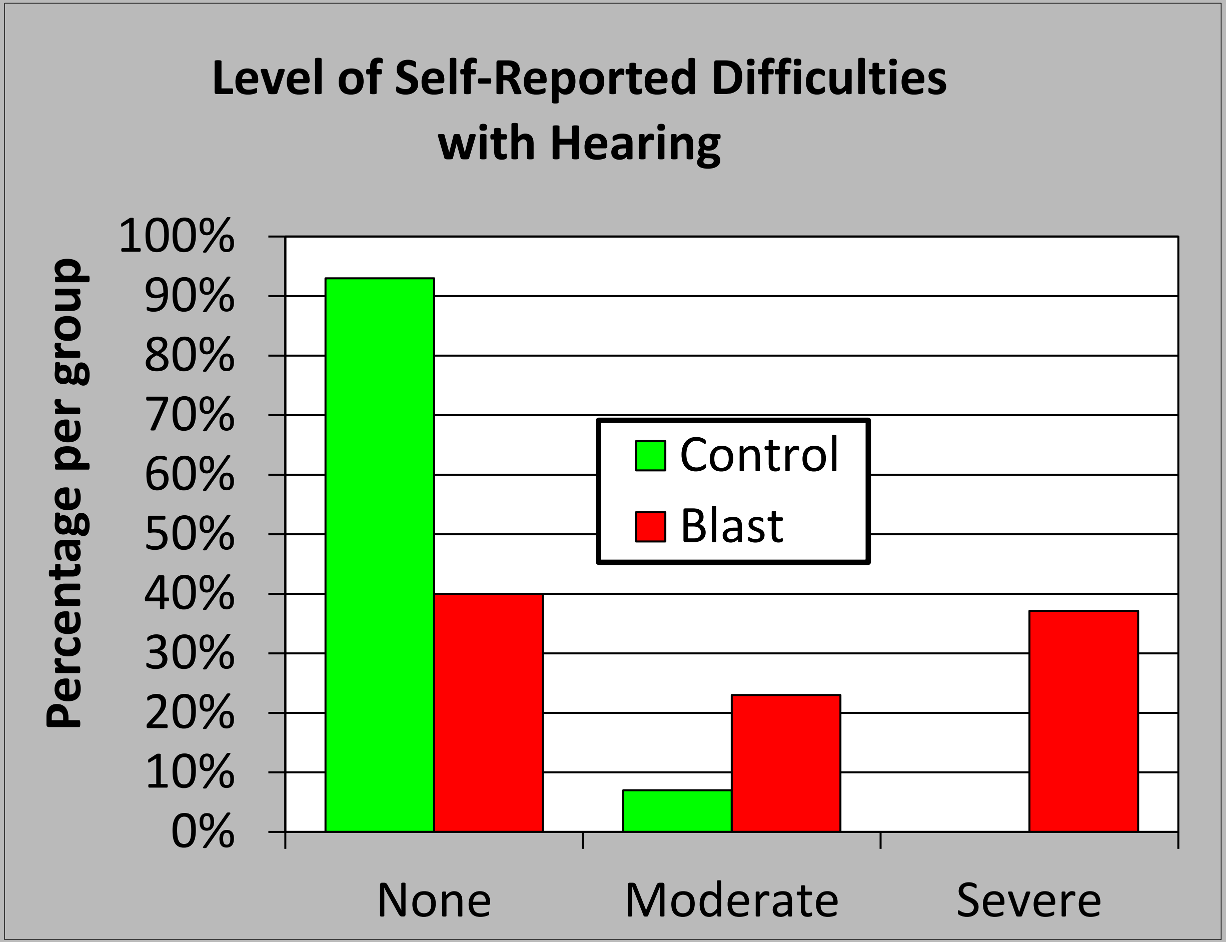
49% Reported some level of difficulty with their hearing

Theodoroff, Papesh, Duffield, Novak, Gallun, King , Chesnutt , Rockwood, Palandri, Hullar (2020) Concussion Management Guidelines Neglect Auditory Symptoms, *Clinical Journal of Sport Medicine*.



Self-Report: Hearing Handicap Inventory – Adult

25-item questionnaire addressing the impact of hearing-related problems on emotional and social functioning



- **BLAST GROUP**: ***30 blast-exposed Veterans***

  Mean age: **37.3 years** (sd 11.5), all with hearing thresholds within normal limits

  Average time since blast exposure: **8.0 years**

  Average number of blasts reported: **5.1 blasts (Range: 1-40; Median: 3)**

- **CONTROL GROUP: *29 age- and hearing-matched participants with no history of brain injury*. Both civilians and Veterans.**

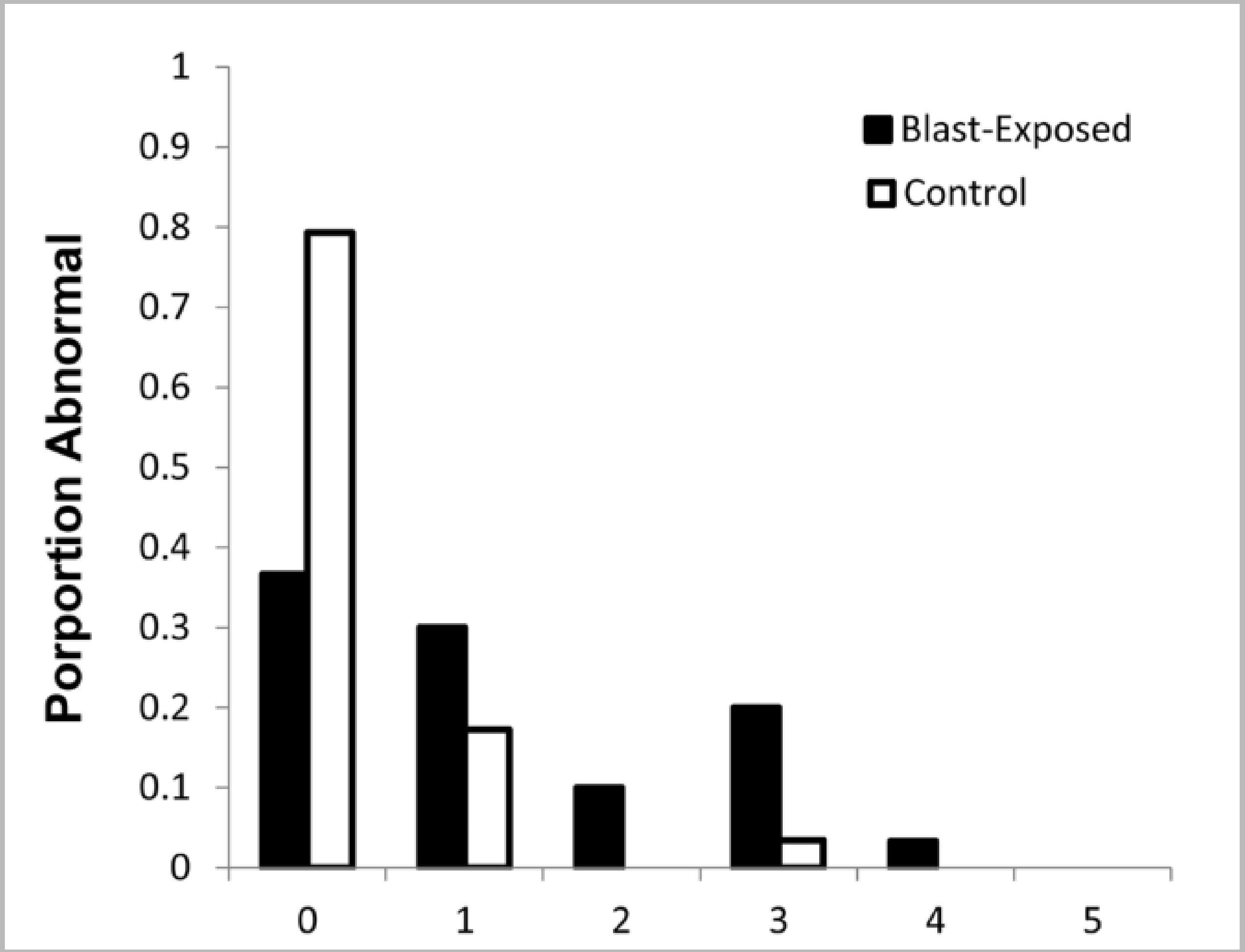
JRRD Volume 53, Number 6, 2016
Pages ???–???

Chronic effects of exposure to high-intensity blasts: Results of tests of central auditory processing

Frederick J. Gallun, PhD;[1–2*] M. Samantha Lewis, PhD;[1–2] Robert L. Folmer, PhD;[1–2] Michele Hutter, MS;[1] Melissa A. Papesh, PhD;[1] Heather Belding, BS;[1] Marjorie R. Leek, PhD[1–3]

[1]National Center for Rehabilitative Auditory Research, Department of Veterans Affairs (VA) Portland Health Care System, Portland, OR; [2]Department of Otolaryngology/Head & Neck Surgery, Oregon Health & Science University, Portland, OR; [3]VA Loma Linda Healthcare System and Department of Otolaryngology/Head & Neck Surgery, Loma Linda University Healthcare, Loma Linda, CA

Number of Tests with Abnormal Performance



Tests abnormal (out of 5 possible)

Percent abnormal on one or more test:

Control (n=29): 21%
Blast (n=30) : 63%

JRRD Volume 53, Number 6, 2016
Pages ???–???

Chronic effects of exposure to high-intensity blasts: Results of tests of central auditory processing

Frederick J. Gallun, PhD;[1–2*] M. Samantha Lewis, PhD;[1–2] Robert L. Folmer, PhD;[1–2] Michele Hutter, MS;[1] Melissa A. Papesh, PhD;[1] Heather Belding, BS;[1] Marjorie R. Leek, PhD[1–3]

[1]National Center for Rehabilitative Auditory Research, Department of Veterans Affairs (VA) Portland Health Care System, Portland, OR; [2]Department of Otolaryngology/Head & Neck Surgery, Oregon Health & Science University, Portland, OR; [3]VA Loma Linda Healthcare System and Department of Otolaryngology/Head & Neck Surgery, Loma Linda University Healthcare, Loma Linda, CA

Manuscript in Preparation
- Collaboration with Laurie King and Kody Campbell

GOAL: Examine the potential effects of mTBI on auditory spatial processing

PARTICIPANTS: 99 civilians with a recent history of mTBI (15-90 days)

frontiers in NEUROSCIENCE

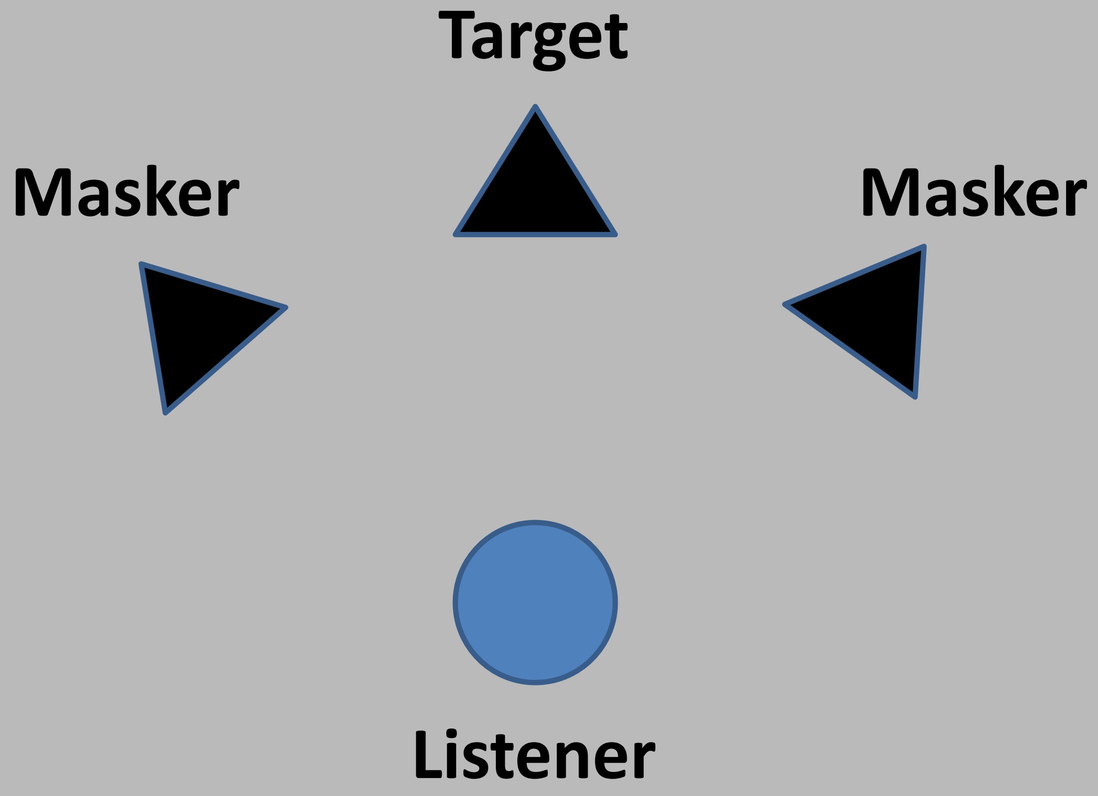
ORIGINAL RESEARCH ARTICLE
published: 23 December 2013
doi: 10.3389/fnins.2013.00252

Independent impacts of age and hearing loss on spatial release in a complex auditory environment

Frederick J. Gallun[1,2]*, Anna C. Diedesch[3], Sean D. Kampel[1] and Kasey M. Jakien[2]

[1] Department of Veterans Affairs, National Center for Rehabilitative Auditory Research, Portland VA Medical Center, Portland, OR, USA
[2] Otolaryngology/Head and Neck Surgery, Oregon Health and Science University, Portland, OR, USA
[3] Hearing and Speech Sciences, Vanderbilt University, Nashville, TN, USA

NIDCD
National Institute on Deafness and Other Communication Disorders



A speech corpus for multitalker communications research

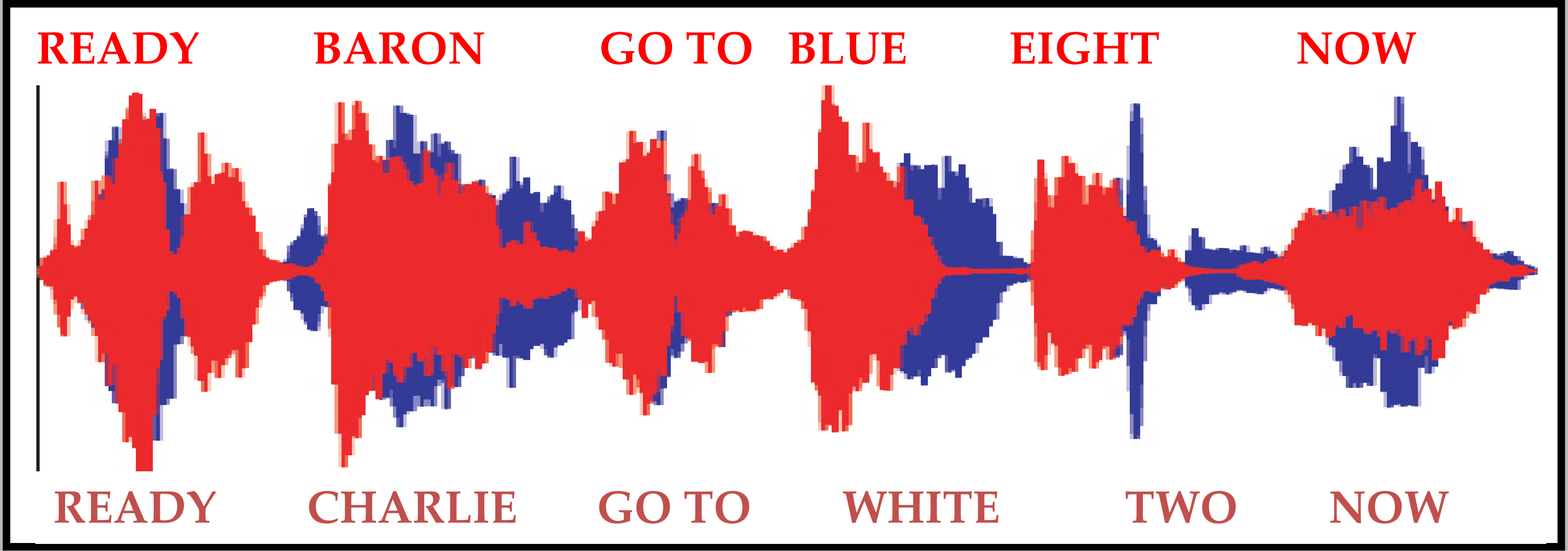
Robert S. Bolia, W. Todd Nelson, and Mark A. Ericson
Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433

Brian D. Simpson
Department of Psychology, Wright State University, Dayton, Ohio 45435

(Received 1 October 1999; revised 18 October 1999; accepted 19 October 1999)

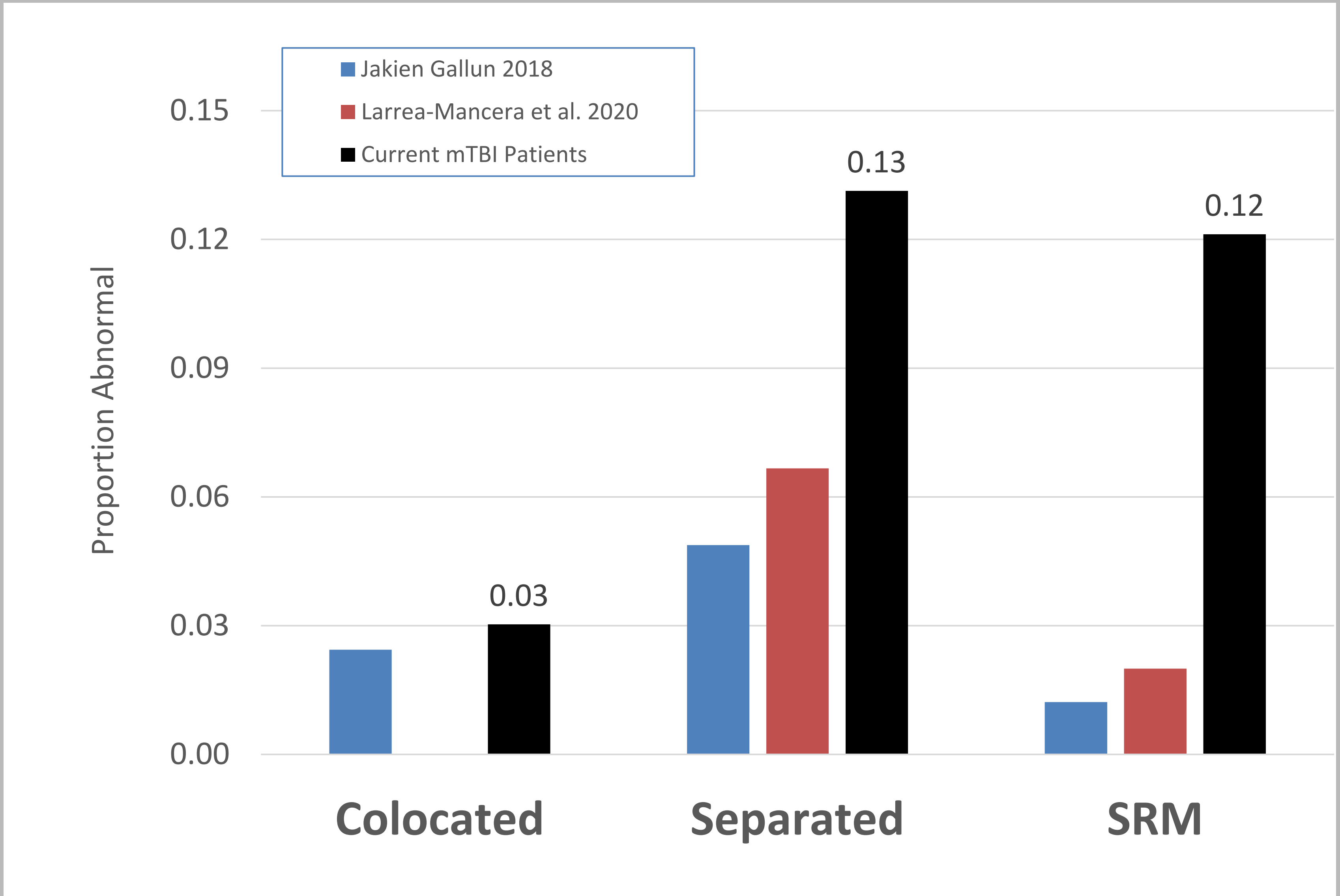
Sentences of the form "Ready [callsign] go to [color] [number] now."

32 possible keyword combinations: 4 colors (red, white, green, blue) and 8 numbers (1 to 8)
8 different callsigns (Baron, Charlie, Hopper, Arrow, Ringo,.
8 talkers: 4 male and 4 female.



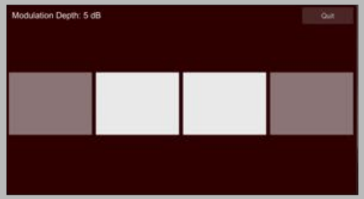
Spatial Offset
Track: 1 Trial: 1
ABORT
Go
BLUE 1 2 3 4 5 6 7 8
RED 1 2 3 4 5 6 7 8
WHITE 1 2 3 4 5 6 7 8
GREEN 1 2 3 4 5 6 7 8

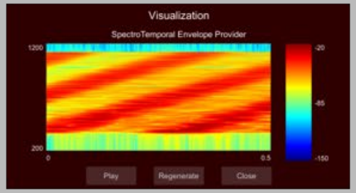
Significantly more patients performed in the abnormal region (2 SD above the mean) in the **Separated** condition and **Spatial Release from Masking (SRM)** as compared to two normative data sets.

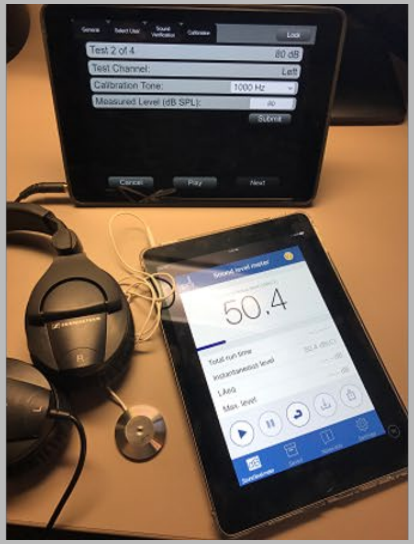


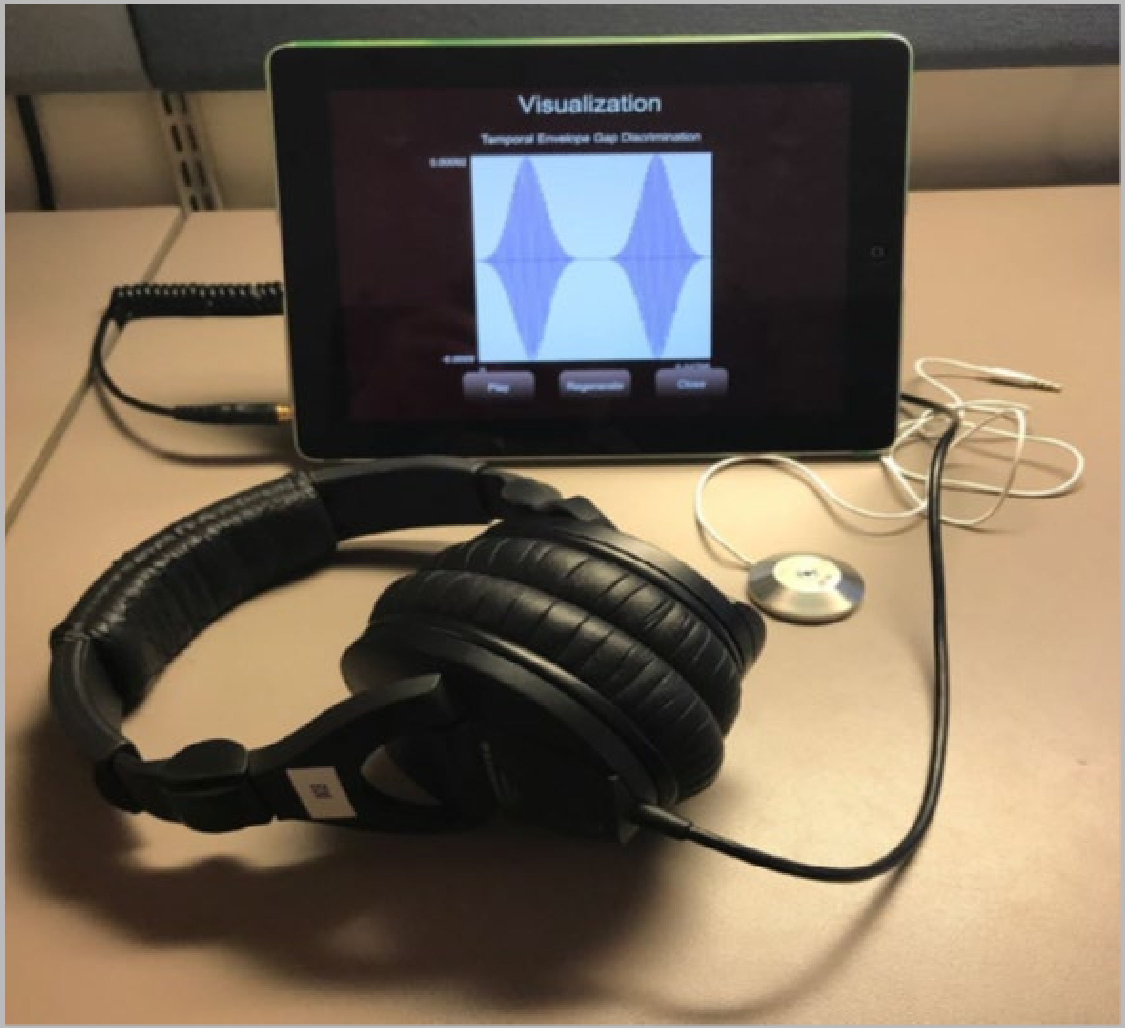
PART 2

- Portable Automated Rapid Testing (PART)
- A New Approach to Auditory Processing Testing





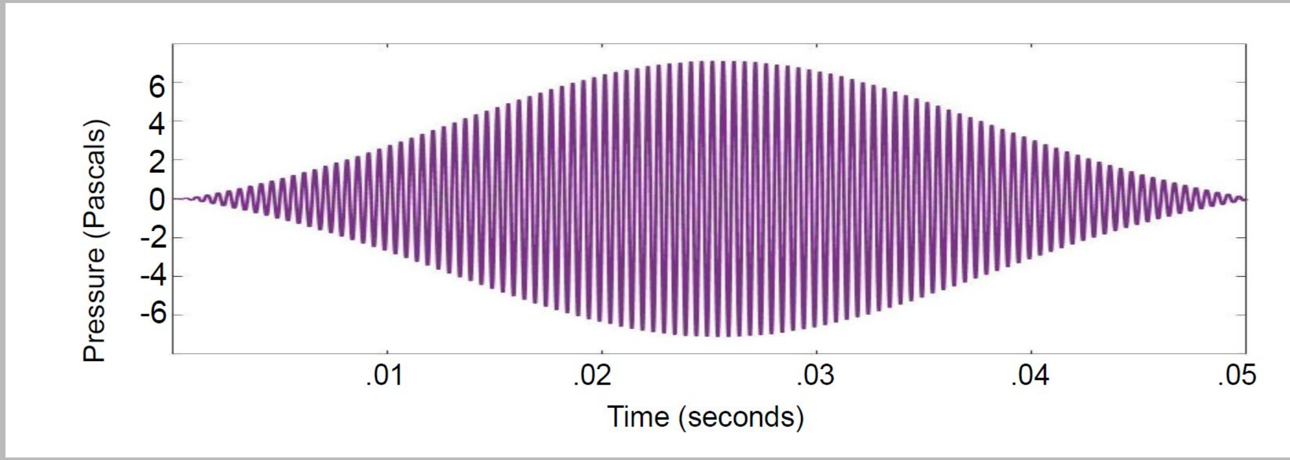


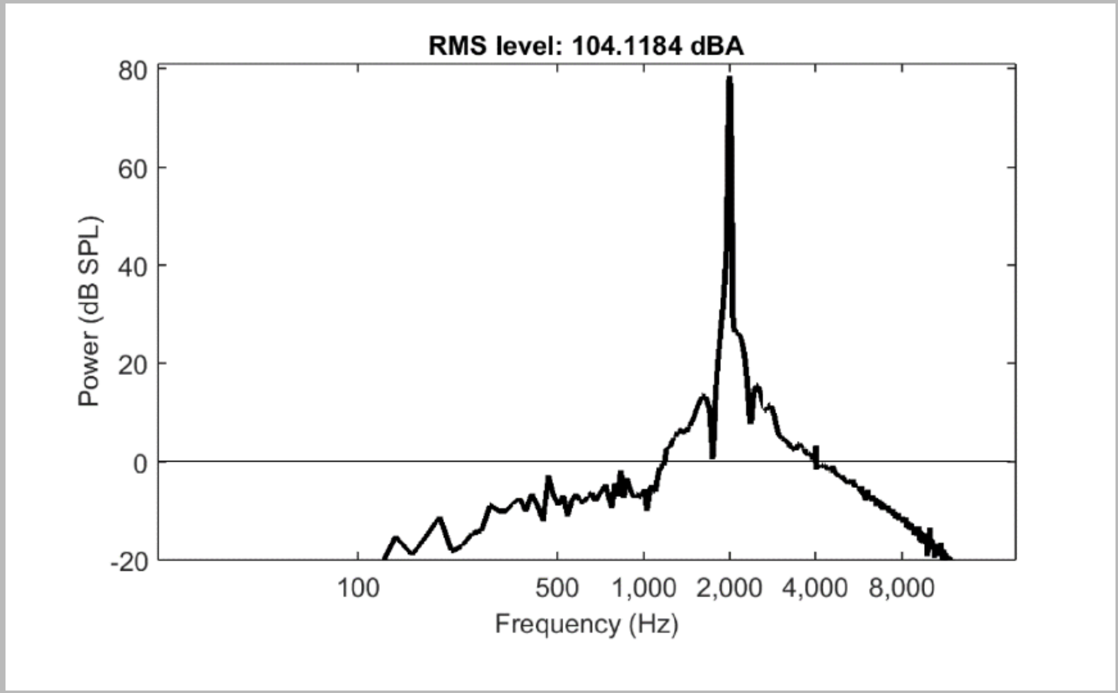


Portable Automated Rapid Testing (PART)

https://bgc.ucr.edu/games

The iPad system is capable of producing laboratory-grade auditory stimuli.





Recording of a single 50 ms tone pulse (2000 Hz carrier) produced at maximum output through iPad Pro and Sennheiser HD280Pro Headphones

Gallun et al. (2018) “Development and validation of Portable Automated Rapid Testing (PART) measures for auditory research”, Proc Meetings Acoust., 33, 050002

Portable psychoacoustics with passive and active noise-attenuating headphones

E. Sebastian Lelo de Larrea-Mancera[1], Trevor Stavropoulos[1], Frederick Gallun[2], Eric Hoover[3], David Eddins[4] & Aaron Seitz[1]

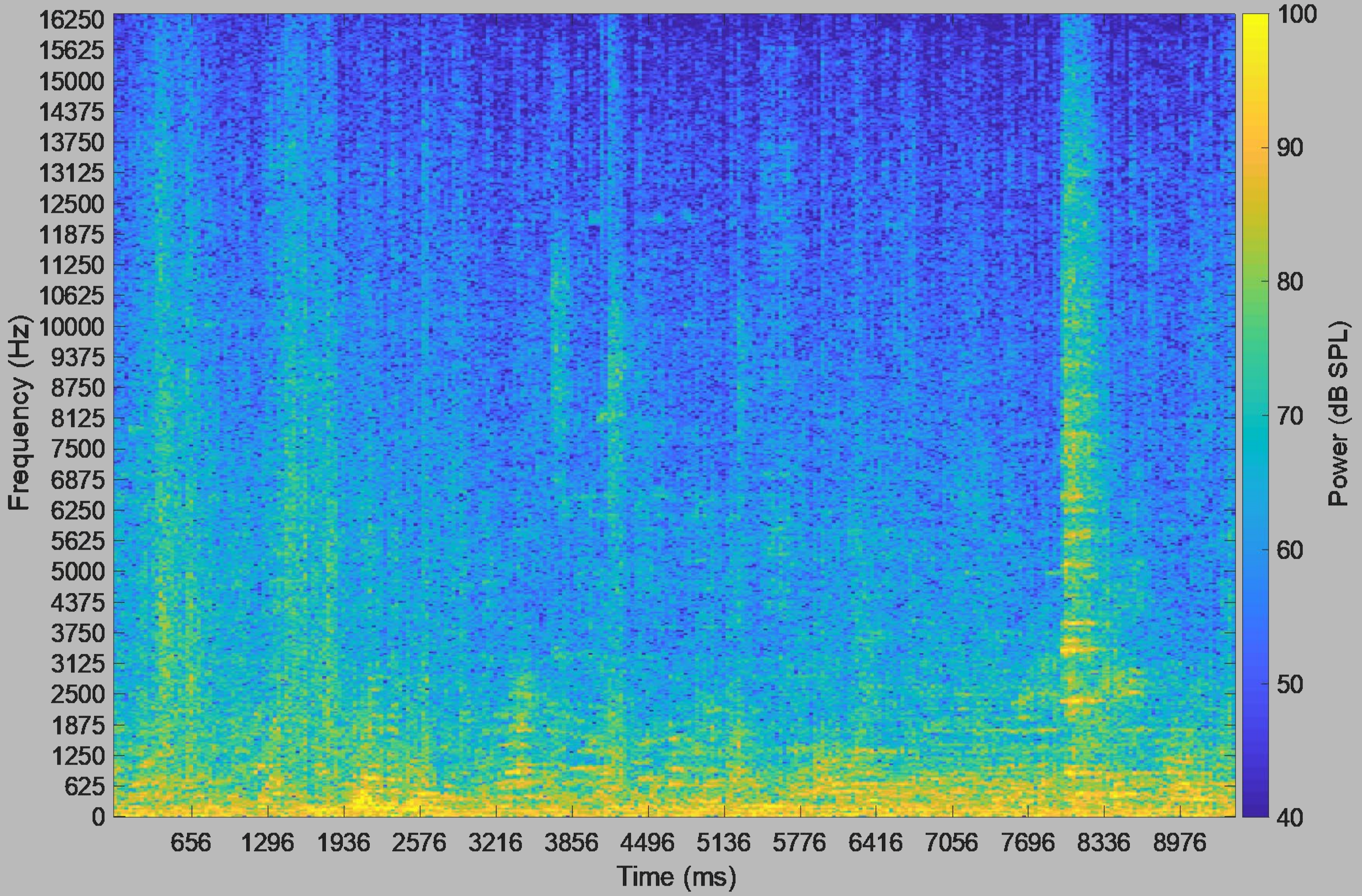
[1]University of California, Riverside, Riverside, CA
[2]Oregon Health and Science University, Portland, OR
[3]University of Maryland, College Park, MD
[4]University of South Florida, Tampa, FL

Participants: 150 undergraduate students from the University of California, Riverside (47 male, mean age=19.3, SD=2.36)

- Experiment 1 (Sennheiser headphones in silence).- 51 participants tested with Sennheiser 280 Pro headphones. Two test sessions.
- Experiment 2 (headphone comparison in silence).- 51 participants tested twice with both Sennheiser 280 Pro headphones and active-noise cancelling Bose Quiet Comfort 35 headphones. Each participant was tested once with each headphone type with the order of sessions counter-balanced between participants.
- Experiment 3 (headphone comparison in noise).- 48 participants tested in a noisy environment, with methods otherwise identical to Experiment 2.

Noise recorded in a local coffee shop then edited to create a 33 min duration noise file and bandpass filtered (20 to 20,000 Hz).

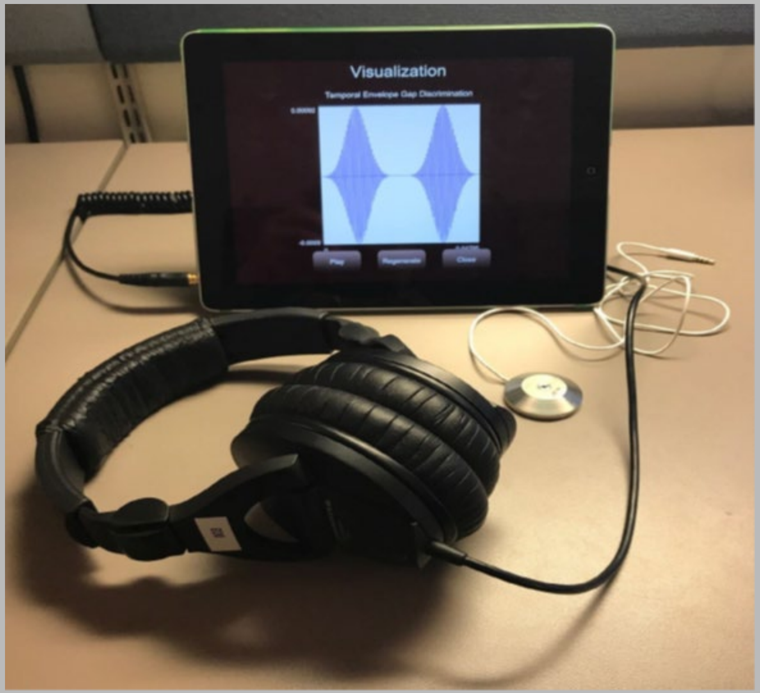
Noise was presented at an average level of 70 dB SPL through a loudspeaker placed 3 meters from the center of the listening room.

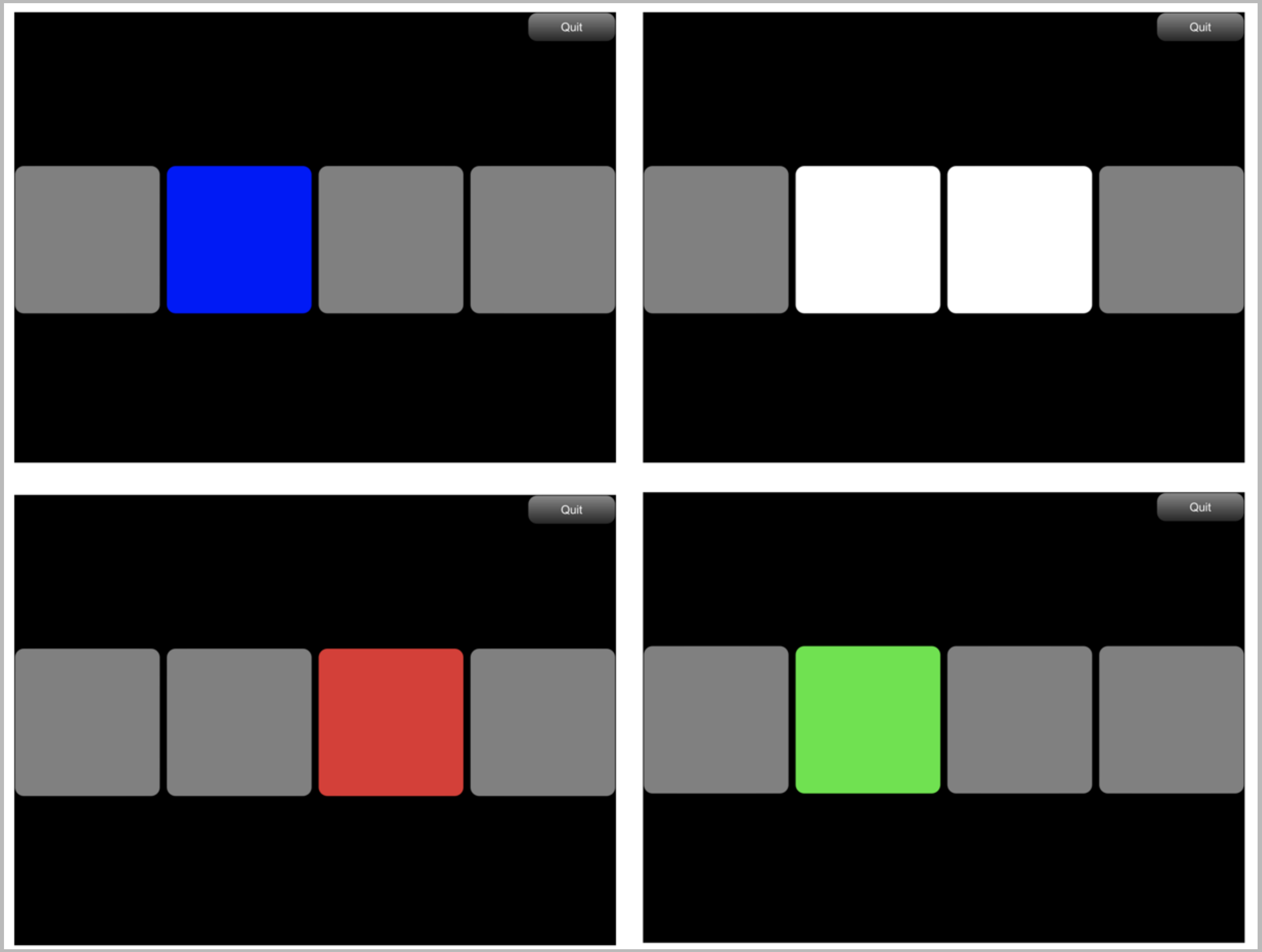


Psychoacoustical Measures of Auditory Function

- Tone in Noise Detection (TN)
- Temporal Modulation (TM)
- Spectral Modulation (SM)
- Spectrotemporal Modulation (STM)
- Gap Detection (GAP)
- Monaural Frequency Modulation (MFM)
- Binaural Frequency Modulation (BFM)

- Spatial Release from Masking (SRM) for Speech in Competition


Visualization
Temporal Envelope Gap Discrimination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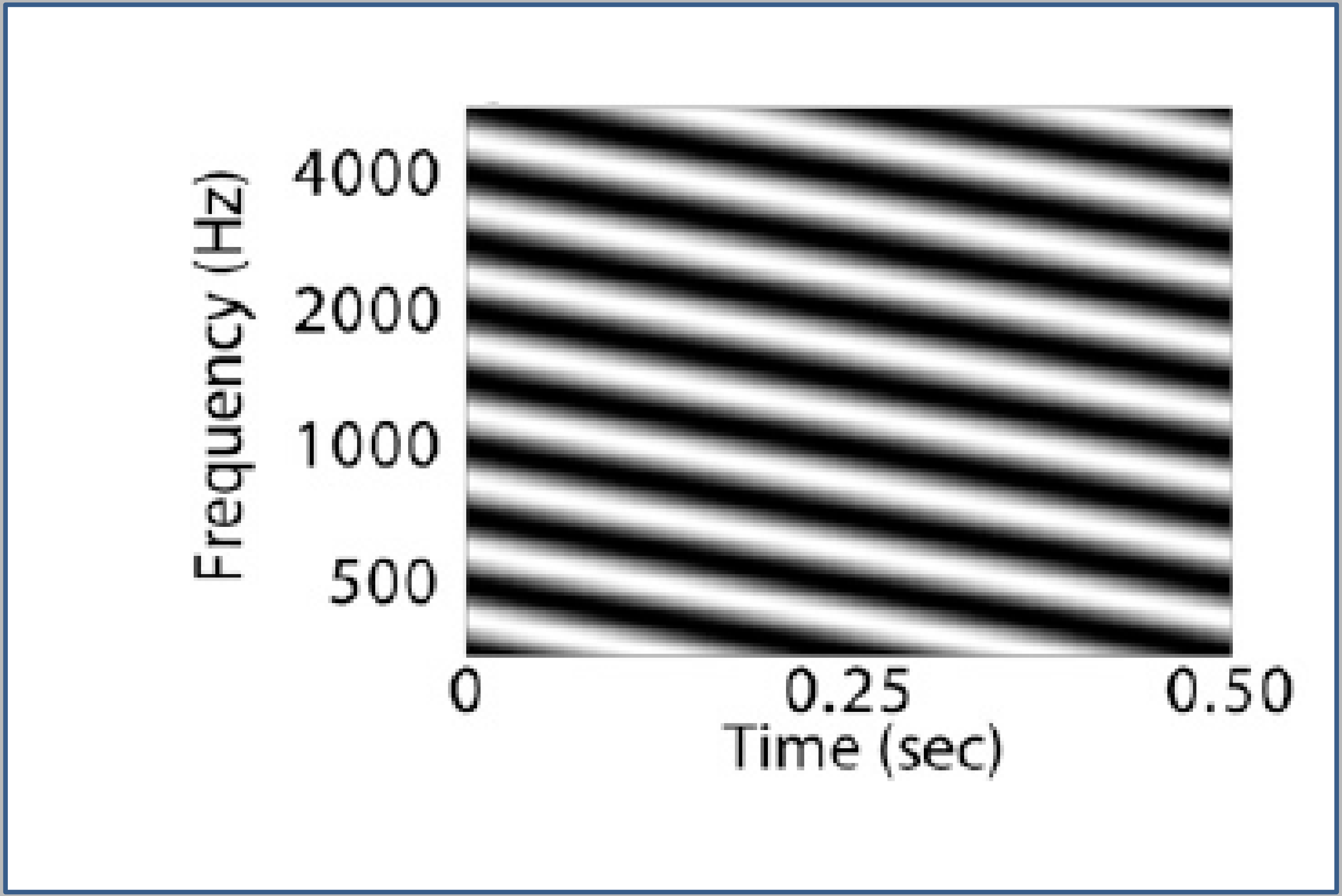
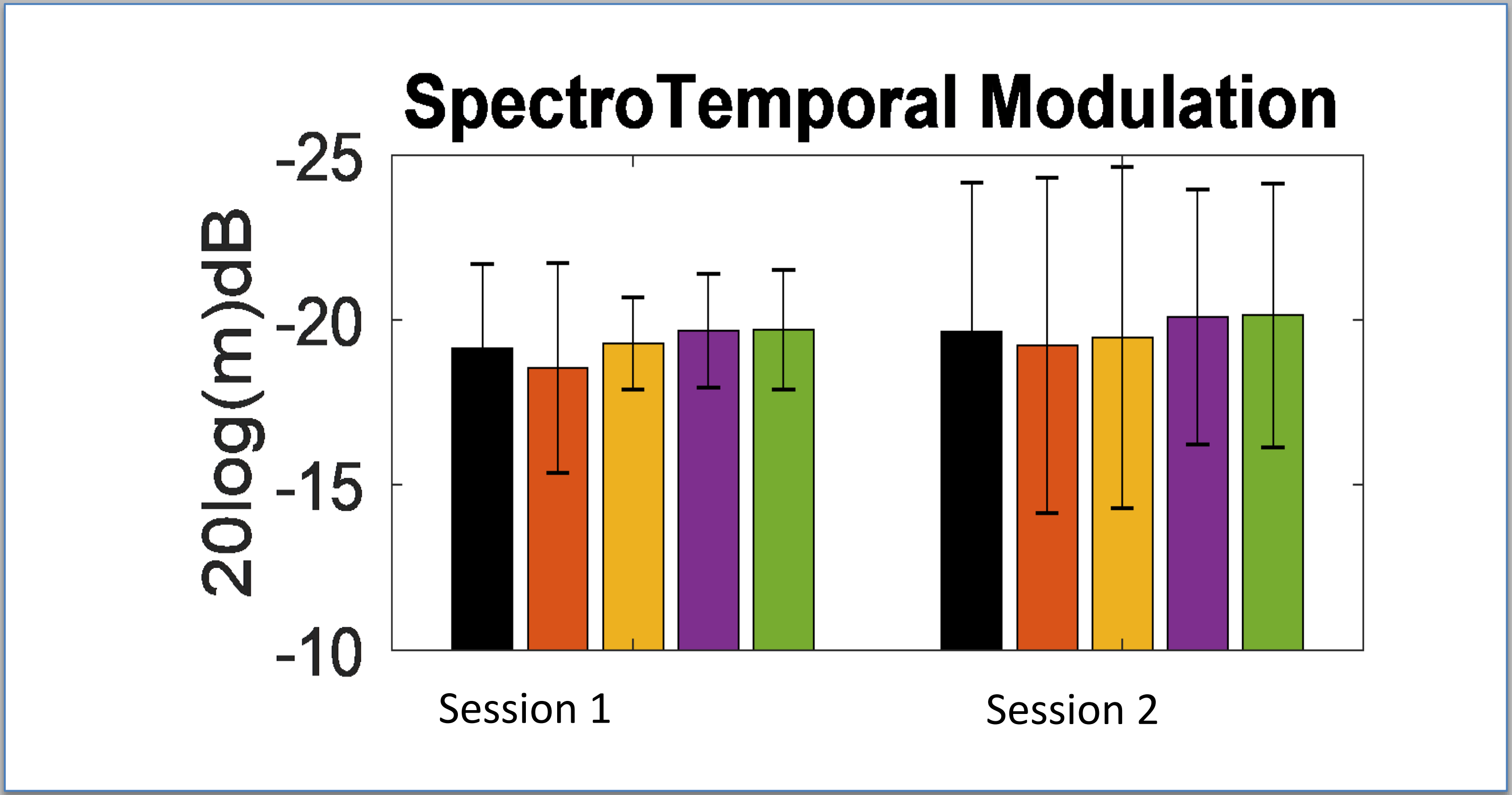
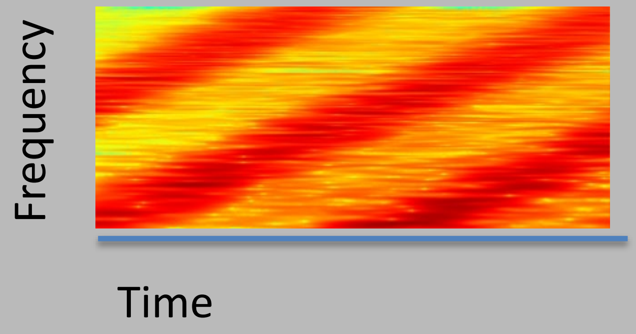
Spectral and Temporal Modulation in an Auditory Stimulus

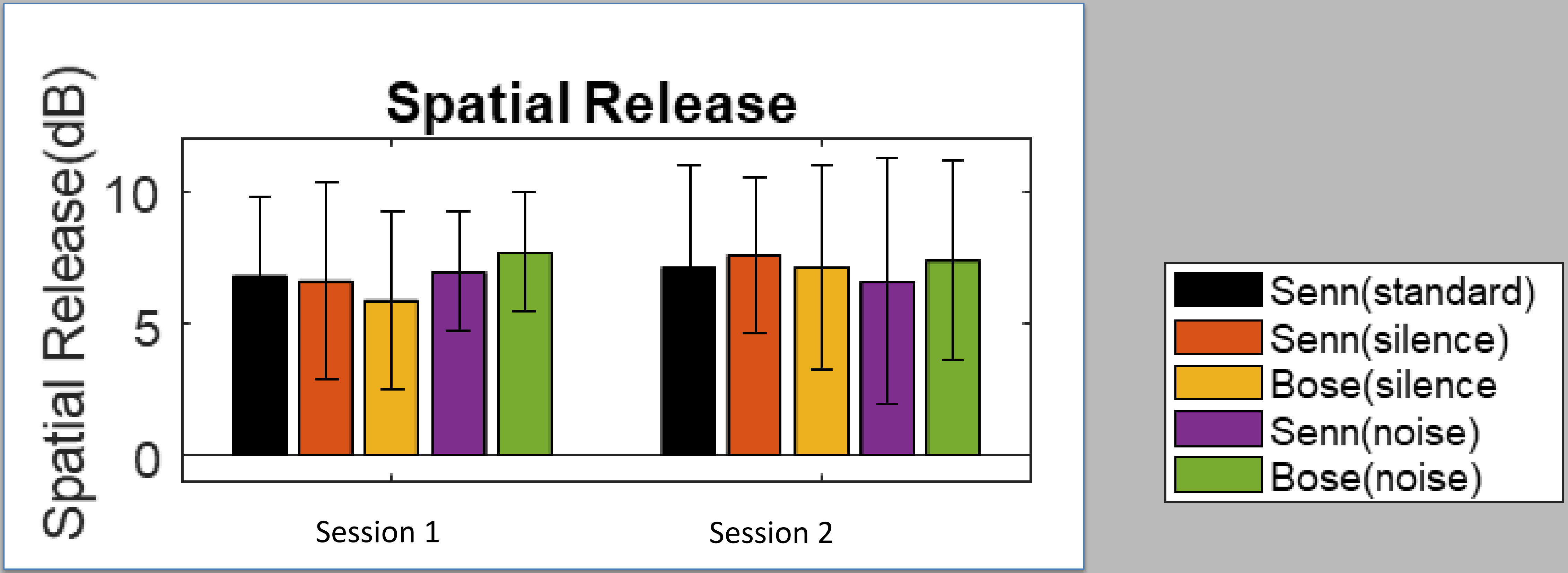


Thresholds for spectrotemporal modulation detection were similar to those obtained in previous work and across all test conditions and sessions





Thresholds (not shown) and spatial release were similar to those obtained in previous work and across all test conditions and sessions (Sesh01 vs Sesh02)



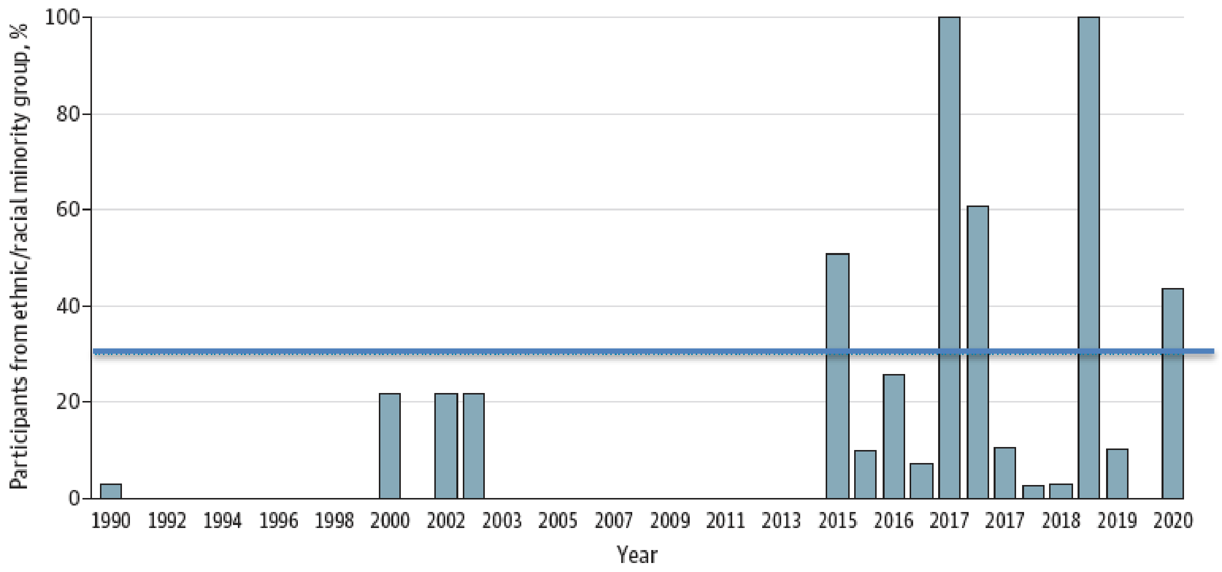
The Need for Representative Data

Among 125 clinical studies performed from January 1990 to July 2020 regarding hearing loss management, only 16 (12.8%) reported race/ethnicity, and 88 (70.4%) reported sex.

Of the 16 studies that reported race/ethnicity, only 5 included more than 30% non-White representation.

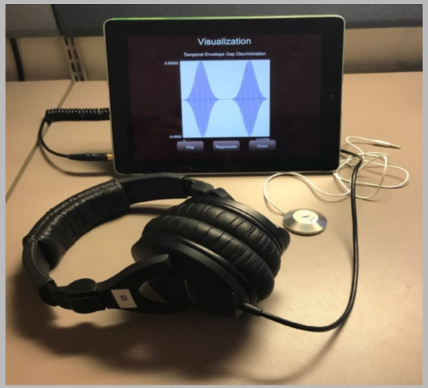
Among the 88 articles that reported sex, 44 (35.2%) reported more than 45% female representation.

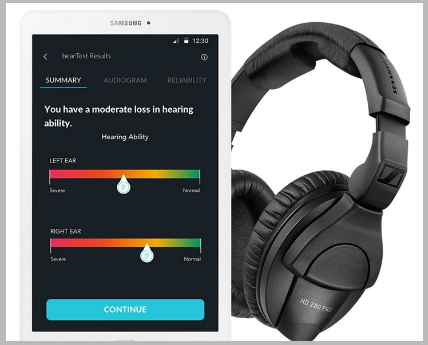
Figure. Ethnic/Racial Minority Group Representation in Hearing Loss Trials by Year

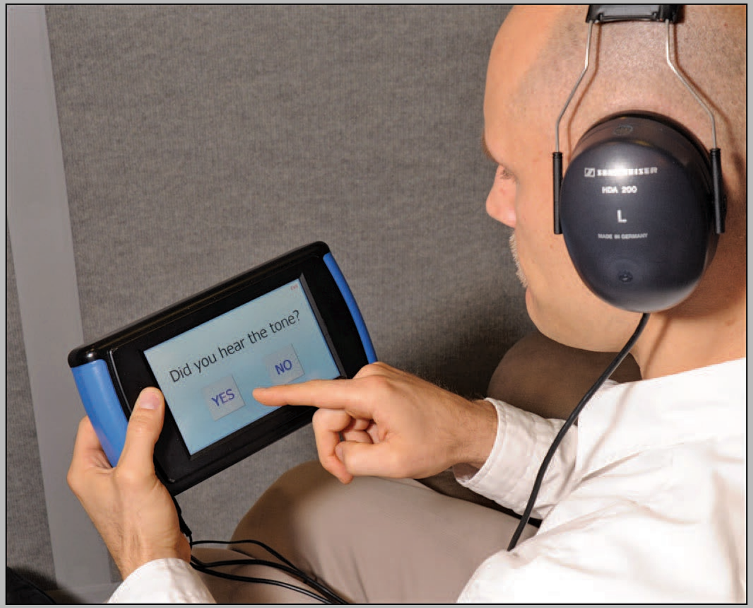


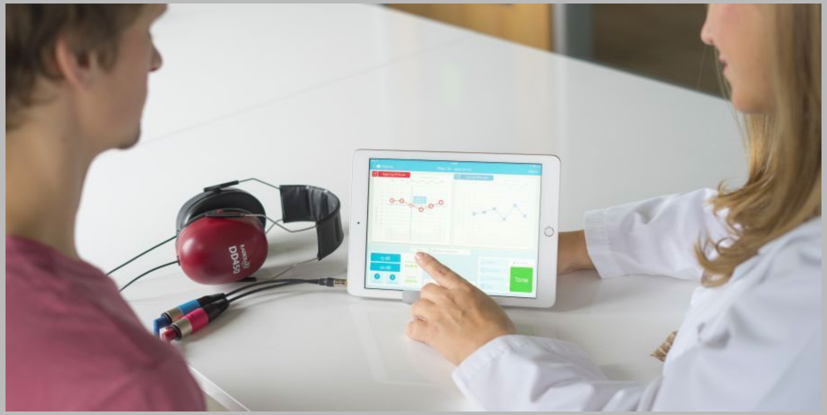
Pittman, C. A., Roura, R., Price, C., Lin, F. R., Marrone, N., & Nieman, C. L. (2021).
Racial/Ethnic and Sex Representation in US-Based Clinical Trials of Hearing Loss Management in Adults: A Systematic Review.
JAMA Otolaryngology-- Head & Neck Surgery, *147*(7), 656–662. https://doi.org/10.1001/jamaoto.2021.0550

Portable Automated Testing Can Help









http://spatialhearing.org/remotetesting

HomePage

Remote Testing Wiki

ASA P&P Task Force on Remote Testing

Welcome to the Wiki home of the Task Force on Remote Testing, an initiative of the Technical Committee on Psychological and Physiological Acoustics (PP) of the Acoustical Society of America (ASA). The task force was initiated by ASA PP during Spring 2020 with the goals of identifying and coordinating information on the impacts of remote testing, which became particularly acute during the COVID-19 Pandemic. At that time, quarantine and social-distancing recommendations began to limit opportunities for in-lab data collection with human research participants. Thus, a major focus of the task force has been to gather information about approaches to data collection outside the lab, for example in participants' own homes, during the pandemic. At the same time, we recognize other potential advantages of remote testing, such as large-N studies and access to special populations, which transcend pandemic-specific impacts. Thus, a broader goal has been to gather and present information relevant to future attempts to collect data outside the laboratory, e.g. "flipping the lab," studies of perception in natural settings, kiosk- and web-based surveys, telehealth, etc.

ASA P&P Task Force on Remote Testing

http://spatialhearing.org/remotetesting

1. What does the platform support in terms of study flow logic, instructions, debriefing, and early termination?

Platform	Supports control of study flow logic	Provides instructions	Provides debriefing	Supports early termination
Amazon MTurk	YES	NO	NO	YES
Cognition.Run	YES	YES	YES	YES
Django	YES	YES	YES	YES
Gorilla	YES	YES	YES	YES
hearX		YES		
ispring	YES	YES	YES	YES
Jacoti	YES	YES	YES	YES
jspsych	NO	YES	YES	YES
MATLAB	YES	YES	YES	YES
PART/BGC Science	YES	YES	YES	YES
Prolific	YES	YES	NO	YES
Psychstudio	YES	YES	YES	YES
PsyToolkit	YES	YES	YES	YES
Qualtrics	YES	YES	YES	YES
SHOEBOX		YES	YES	
SpeakPipe	NO	NO	NO	YES
TabSINT	YES	YES	YES	YES
TeamHearing	YES	YES	YES	YES

Platforms

There are numerous possible approaches to remote testing. Some involve completely custom investigator-designed procedures and stimulus/response apparatus; others leverage existing general-purpose computing platforms, e.g. for presenting surveys on the web. In this section, we use the term "Platform" to refer to any hardware/software/network system that can be used to support remote testing. Platforms vary tremendously: some are comprehensive online tools that support recruiting, consenting, screening and paying participants, presenting and manipulating experimental stimuli, collecting, tabulating, and transmitting response data, and even tracking project progress; others are limited to one or more of these activities. Platforms also vary based on the level of support (commercial vs open source vs in-house), goals, and capabilities. Some of those differences are discussed in abstract terms on the Platform Considerations page.

In May 2020, the Psychological and Physiological (PP) Acoustics Technical Committee of the Acoustical Society of America formed a Task Force on Remote Testing. Their discussions resulted in this Wiki and an evolving detailed description of the platforms available for Remote Testing. The descriptions in this section focus is on describing the specific capabilities of identified platforms, as obtained via a survey of users conducted by the PP Remote Testing Task Force. These descriptions were accurate as of July 8, 2020 - to the best of our knowledge - and will be updated as platforms are created, become obsolete, and otherwise evolve.

spatialhearing.org/remotetesting/Resources/Resources

Apps MetaFrame OHSU Citrix OHSU Webmail eRA Commons » Other Bookmarks Reading List

Recent Changes - Search: Go

Main
- Issues
- Platforms
- Examples
- Resources
- FAQ
- Task Force

Resources
- Review Papers
- Approach Papers
- Use Papers
- Other Papers
- Online Resources

- Web-based Platforms
- Hardware Platforms
- Code Packages
- Commercial Solutions
- Recruitment
- Monitoring

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Resources /

Resources

Papers and informational resources

- Papers with broad/introductory reviews to remote testing
- Papers, theses, proceedings, and preprints that describe and/or validate remote testing approaches
- Other articles/projects that use remote testing
- Other articles that describe auditory environments that remote testing may occur
- Other online informational resources

Platform links (for full descriptions see Platform Descriptions)

- All-in-one web-based solutions (experiment development and hosting)
- Take-home/hardware-based solutions
- Code libraries/packages/toolkits (manual hosting required)
- Ready-made and commercial solutions (primarily for hearing screening)
- Recruitment
- Monitoring

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Resources /

HardwarePlatforms

- Web-based Platforms
- Hardware Platforms
- Code Packages
- Commercial Solutions
- Recruitment
- Monitoring

Take-home/hardware-based solutions

For full descriptions see Platform Descriptions. Also see ready-made and commercial solutions below for prebuilt take-home options.

PART/BGC Science https://ucrbraingamecenter.github.io/PART_Utilities
- PART is intended to be used as a stand-alone psychoacoustical test platform, capable of providing identical assessments to large numbers of participants across multiple sites.

TabSINT https://tabsint.org
- Develop custom hearing-related exams or general-purpose questionnaires, then deploy remotely to tablets and mobile devices at multiple sites

mBrainTrain https://mbraintrain.com
- A mobile EEG device that may be paired with a smartphone or desktop computer

ASA P&P Task Force on Remote Testing

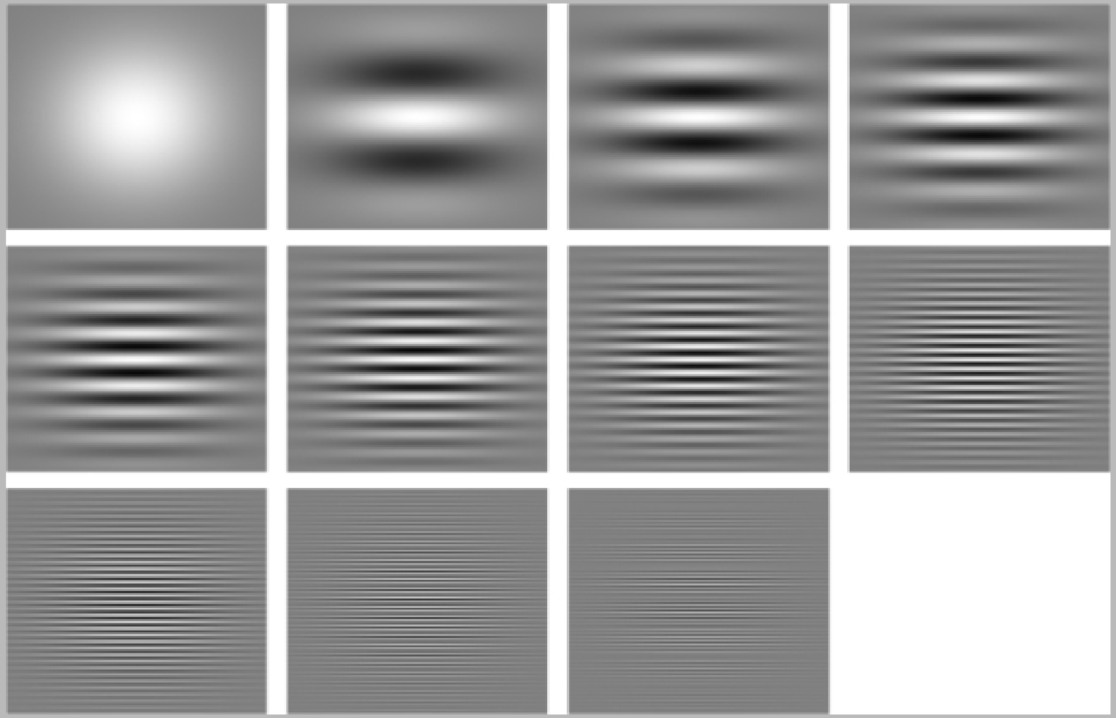
http://spatialhearing.org/remotetesting

PART 3

- LISTEN: An Auditory Training Experience

Eunice Kennedy Shriver NICHD
National Institute of Child Health & Human Development

Training on basic visual features results in learning that transfers to other domains



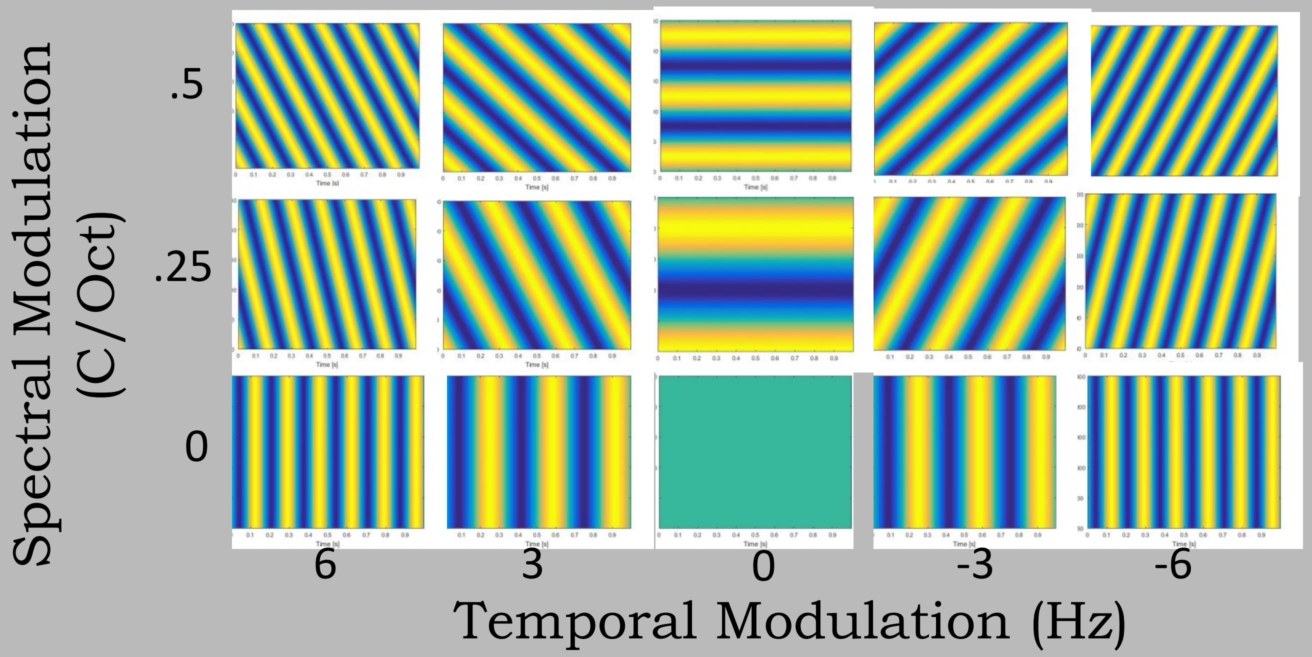
Spatial Frequency (above)
But also: orientation, contrast, spatial location…

Basic tests of vision
Deveau, Lovick & Seitz (2014)

Performance of college athletes
Deveau, Ozer & Seitz (2014)

Reading
Deveau & Seitz (2014)

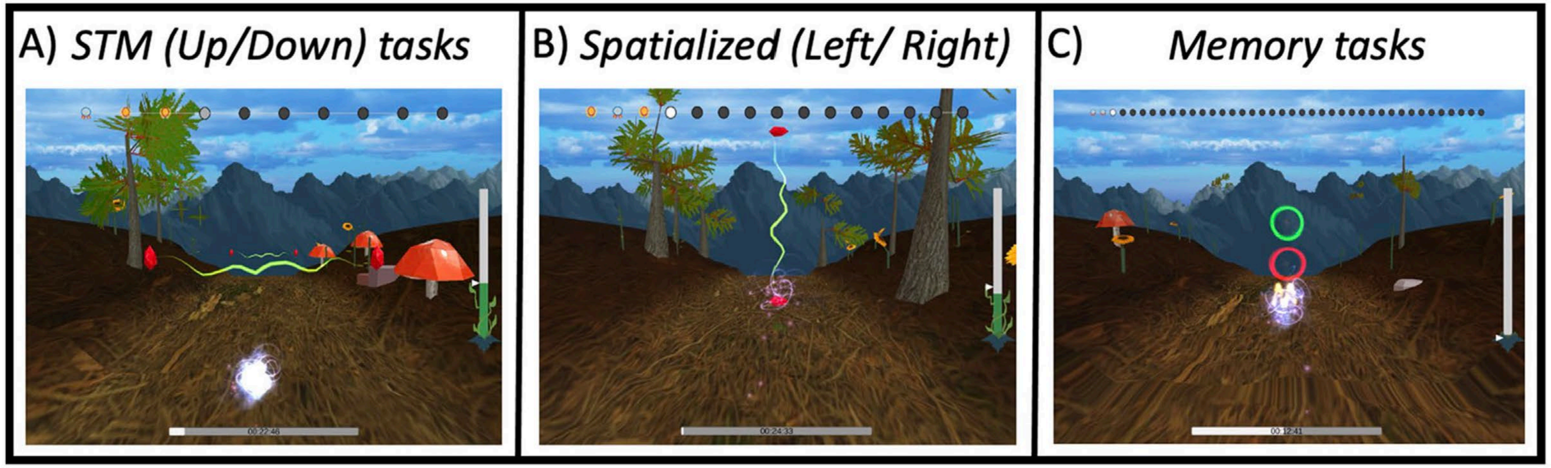
Hypothesis: Training Basic Auditory Features will Transfer to Speech in Noise



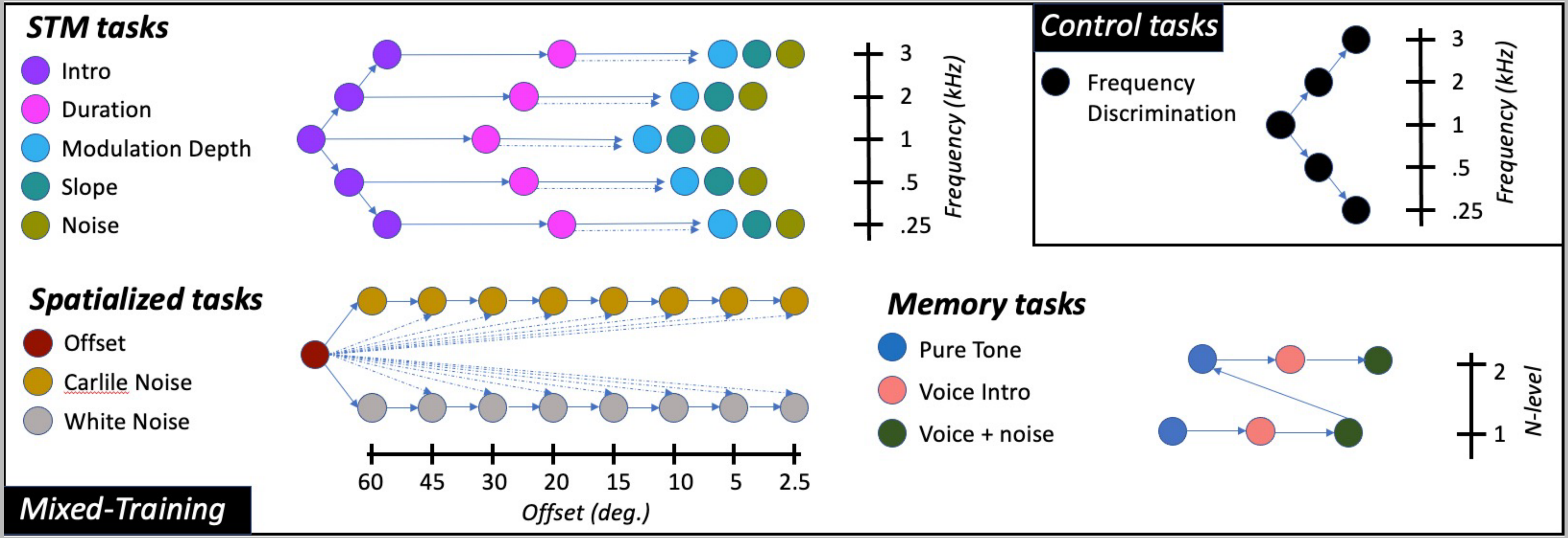
Training with an auditory perceptual learning game transfers to speech in competition

E. Sebastian Lelo de Larrea-Mancera[1,2] · Mark A. Philipp[2] · Trevor Stavropoulos[2] · Audrey Anna Carrillo[2] · Sierra Cheung[2] · Tess K. Koerner[3,4] · Michelle R. Molis[3,4] · Frederick J. Gallun[3,4] · Aaron R. Seitz[1,2]

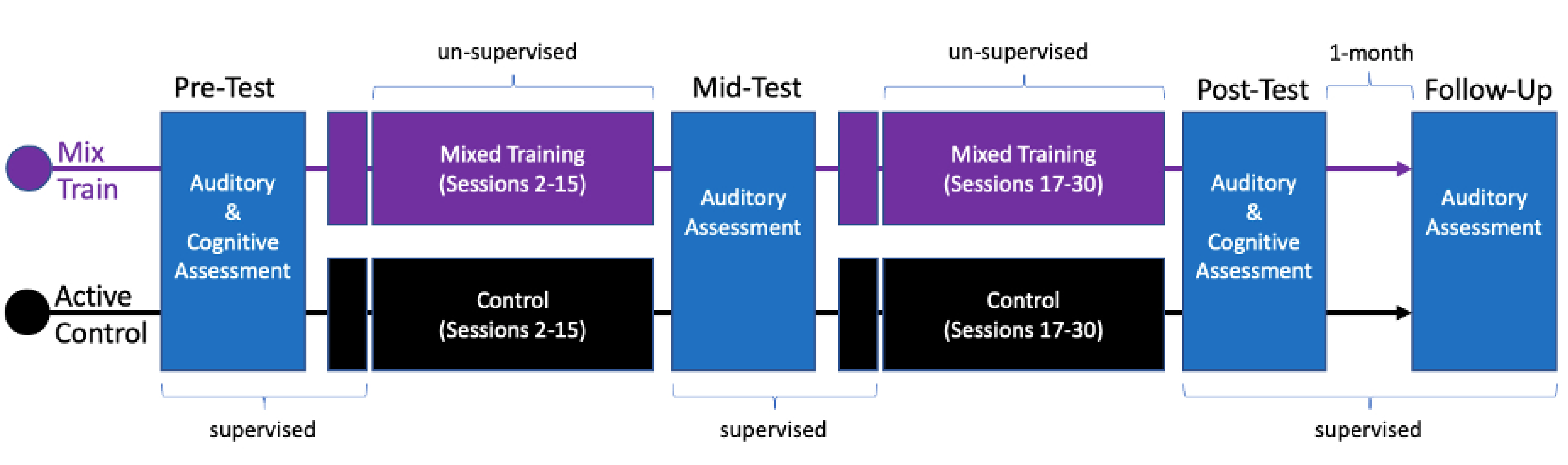
Journal of Cognitive Enhancement
https://doi.org/10.1007/s41465-021-00224-5



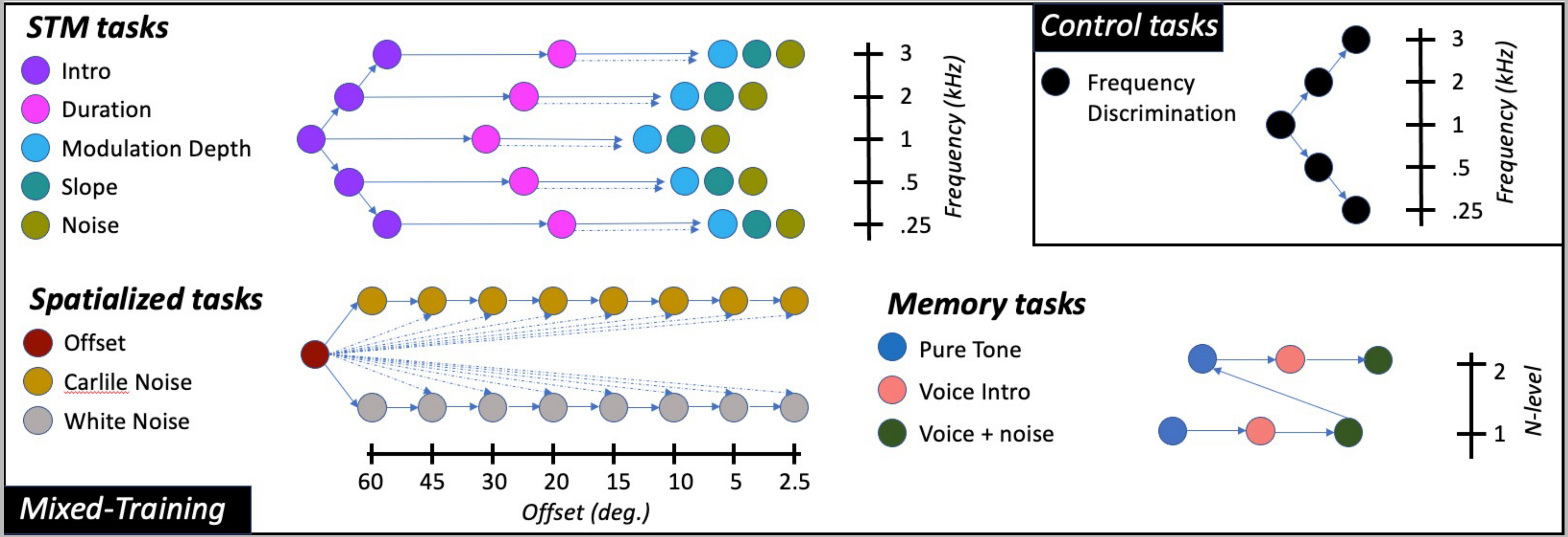
VIDEO of LISTEN STM removed to reduce file size



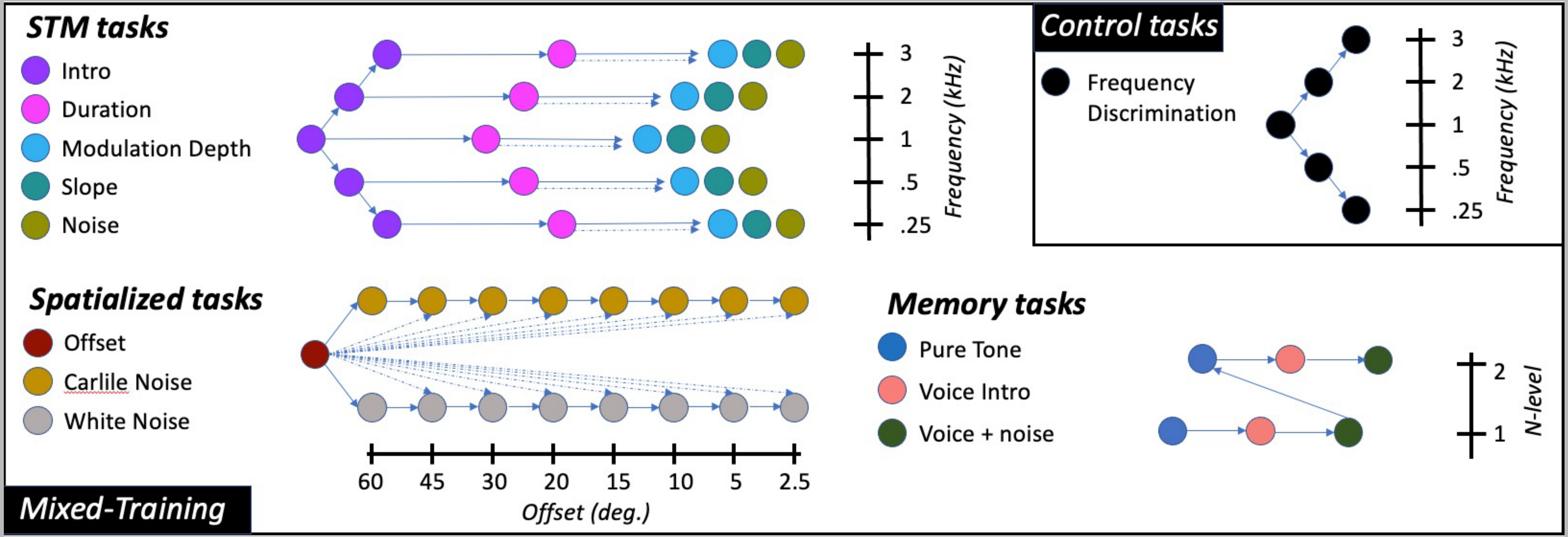
STM tasks
Intro
Duration
Modulation Depth
Slope
Noise
3
2
1
.5
.25
Frequency (kHz)
Control tasks
Frequency Discrimination
3
2
1
.5
.25
Frequency (kHz)
Spatialized tasks
Offset
Carlile Noise
White Noise
60
45
30
20
15
10
5
2.5
Offset (deg.)
Memory tasks
Pure Tone
Voice Intro
Voice + noise
2
1
N-level
Mixed-Training



un-supervised
un-supervised
1-month
Pre-Test
Mid-Test
Post-Test
Follow-Up
Mix Train
Active Control
Auditory & Cognitive Assessment
Mixed Training (Sessions 2-15)
Control (Sessions 2-15)
Auditory Assessment
Mixed Training (Sessions 17-30)
Control (Sessions 17-30)
Auditory & Cognitive Assessment
Auditory Assessment
supervised
supervised
supervised


STM tasks
Intro
Duration
Modulation Depth
Slope
Noise
3
2
1
.5
.25
Frequency (kHz)
Control tasks
Frequency Discrimination
3
2
1
.5
.25
Frequency (kHz)
Spatialized tasks
Offset
Carlile Noise
White Noise
60
45
30
20
15
10
5
2.5
Offset (deg.)
Memory tasks
Pure Tone
Voice Intro
Voice + noise
2
1
N-level
Mixed-Training

VIDEO of LISTEN STM removed to reduce file size



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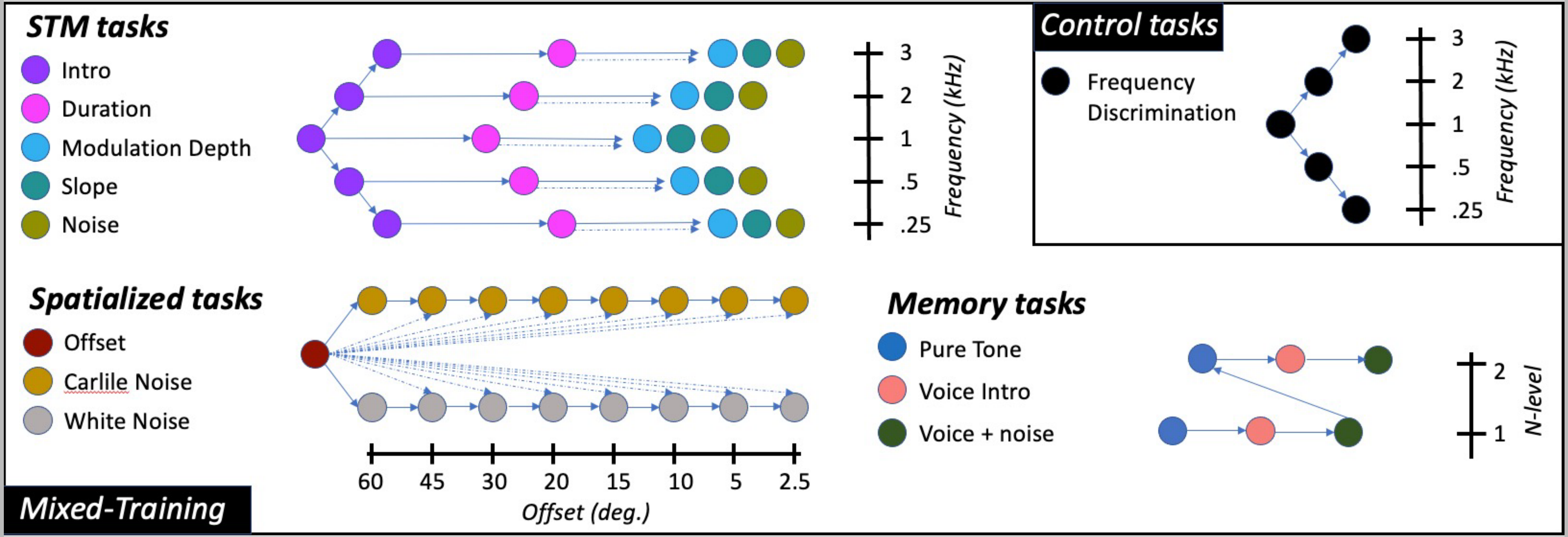
Offset (deg.)
Memory tasks
Pure Tone
Voice Intro
Voice + noise
2
1
N-level
Mixed-Training

VIDEO of LISTEN Spatial task removed to reduce file size


STM tasks
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Voice Intro
Voice + noise
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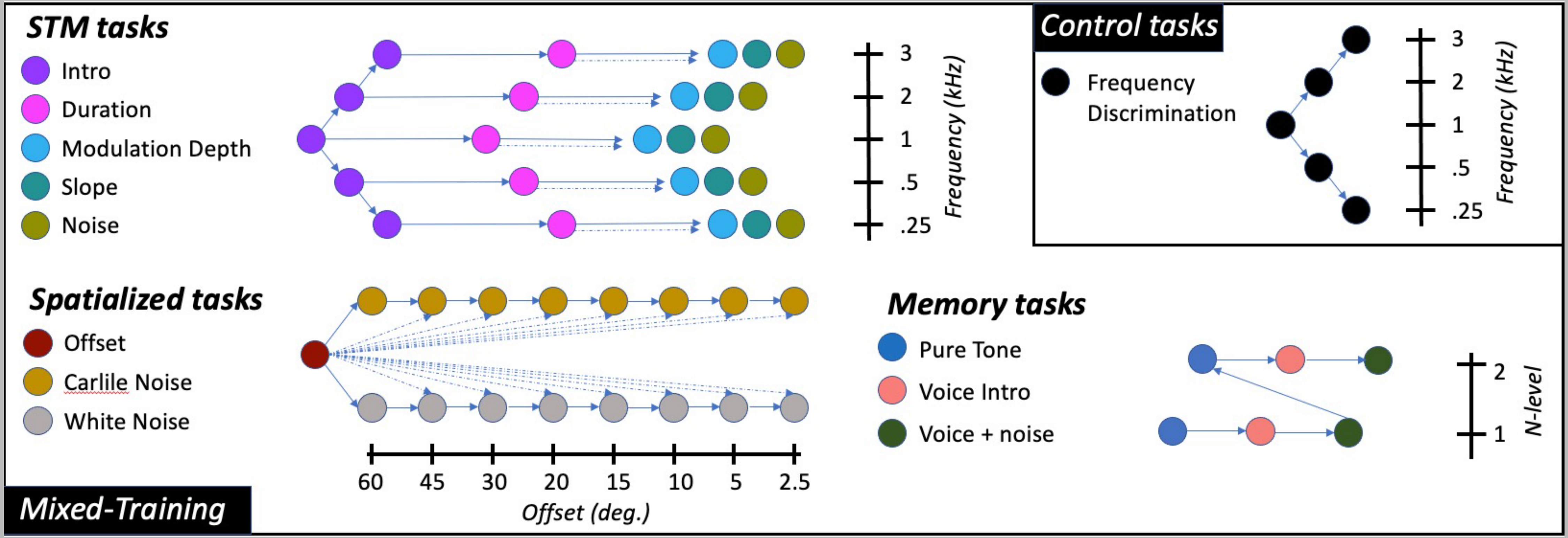
N-level
Mixed-Training

VIDEO of LISTEN Memory task removed to reduce file size


STM tasks
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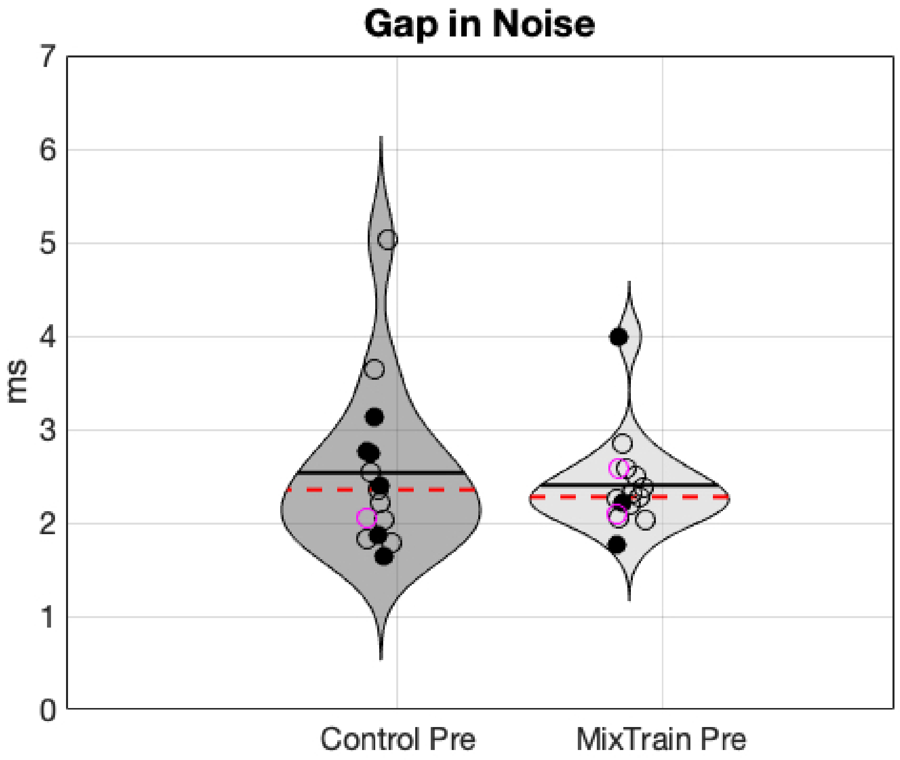
2
1
N-level
Mixed-Training

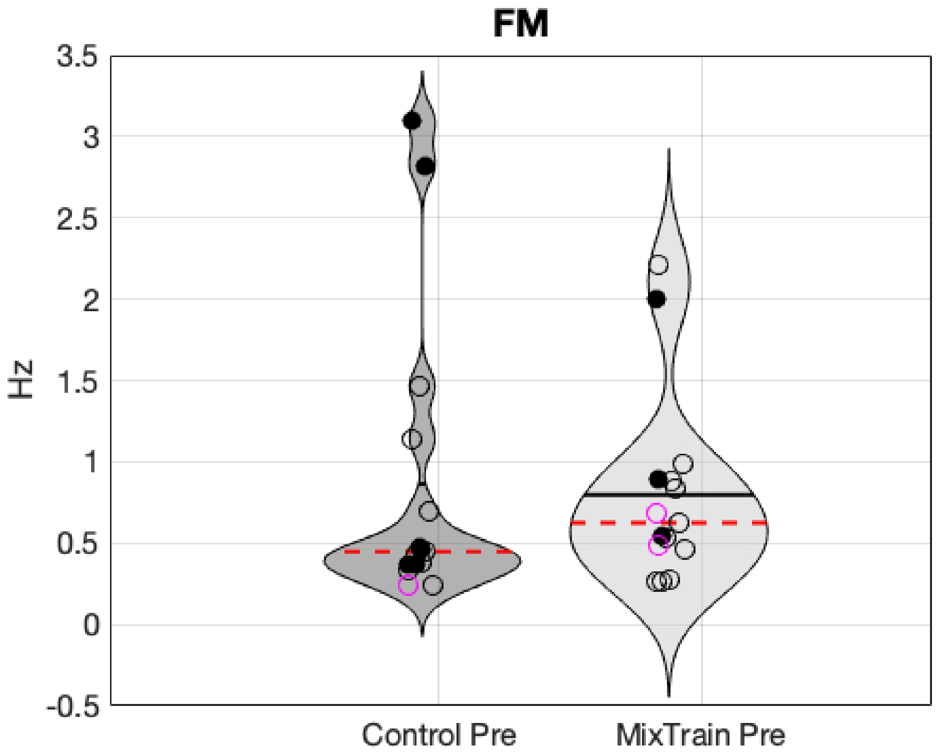
VIDEO of LISTEN Memory task removed to reduce file size

Auditory Assessments: Basic auditory processing

Assessments match literature at pre-test

- GIN (between 2-3 ms) (Florentine et al., 1999)
- FM (*M* = 0.51 *SD* = 2.23) (Larrea-Mancera, 2020)

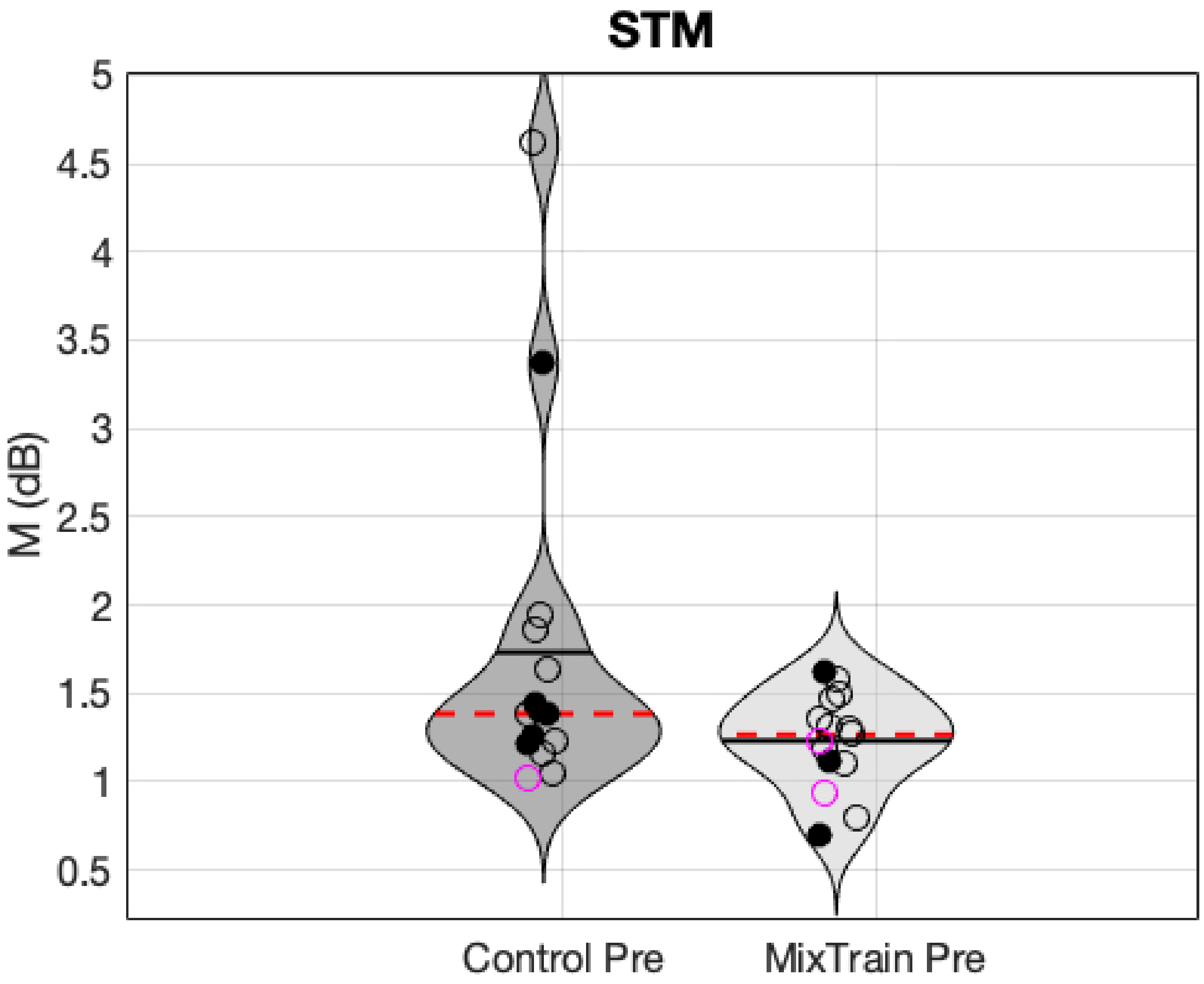




Auditory Assessments: Basic auditory processing

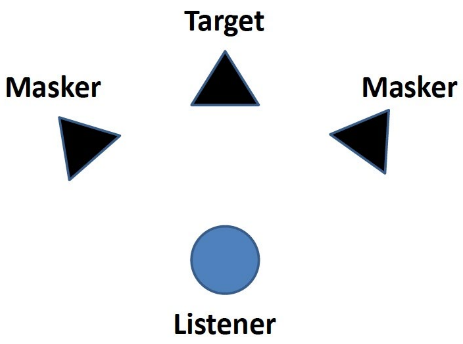
Assessments match literature at pre-test

- STM (M = 0.95 SD = 0.46) (Larrea-Mancera, 2020)



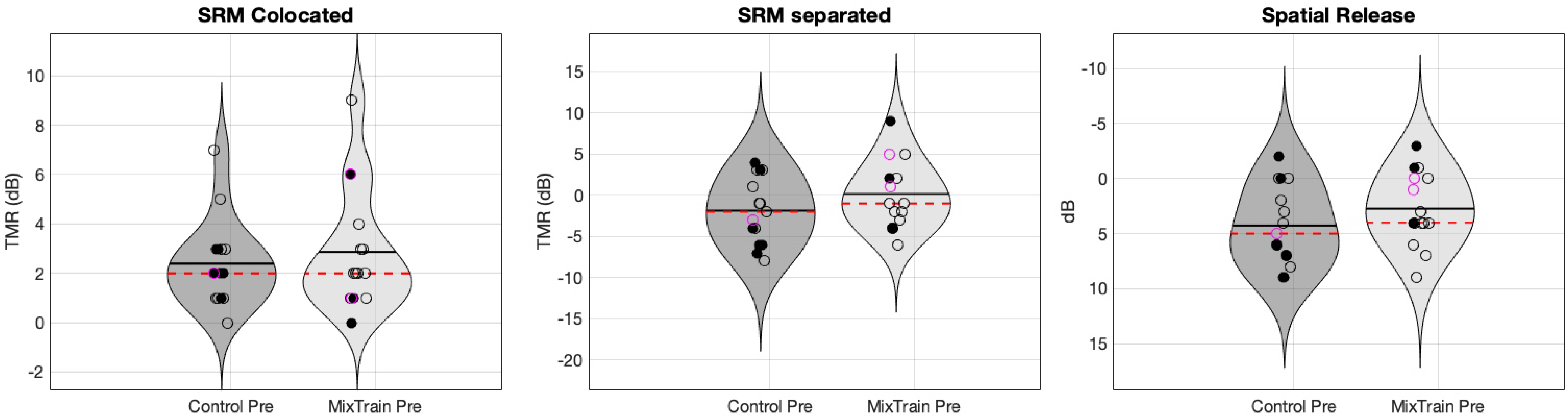
Auditory Assessments: Speech in Competition

<u>Spatial Release from Masking</u>



Assessments match literature at pre-test

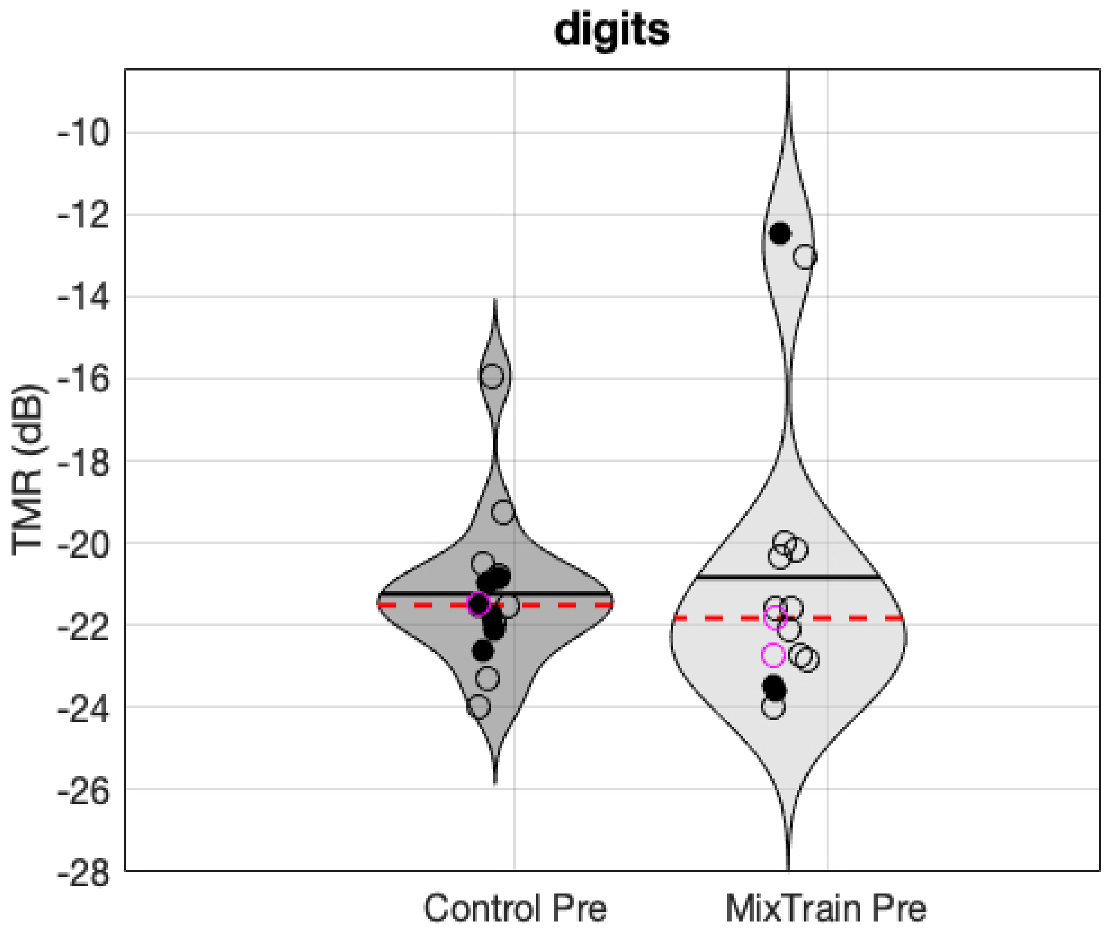
- Colocated (M = 2.1 SD = 1.9) (Larrea-Mancera, 2020)
- Separated (M = -3.9 SD = 3.3) (Larrea-Mancera, 2020)
- SRM (M = 5.8 SD = 3.2) (Larrea-Mancera, 2020)



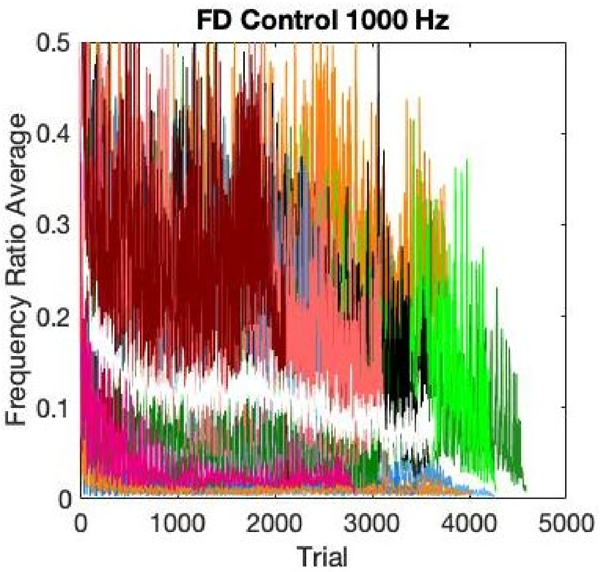
Auditory Assessments: Speech in Competition

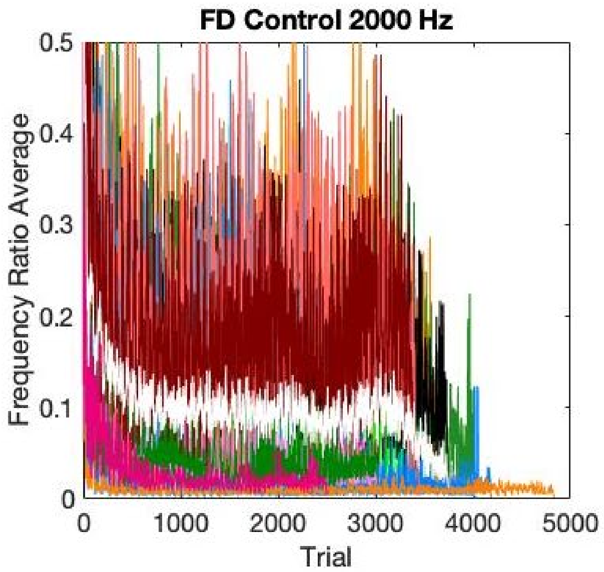
Assessments match literature at pre-test

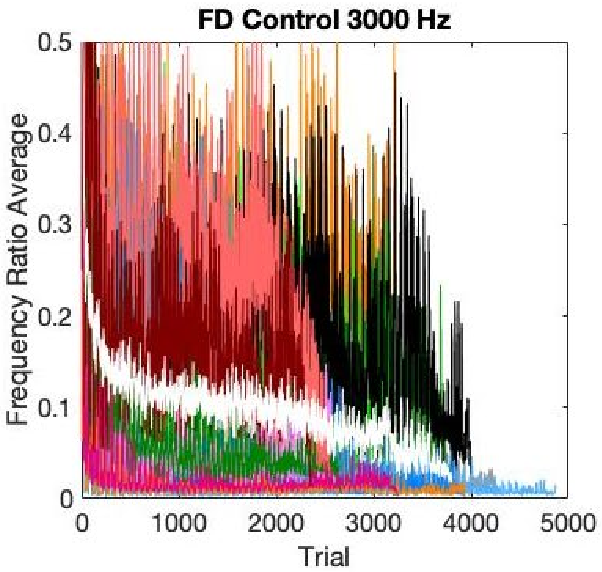
- Digits-in-Noise (M = -8.8 SD = 0.6) (Smits et al., 2013)

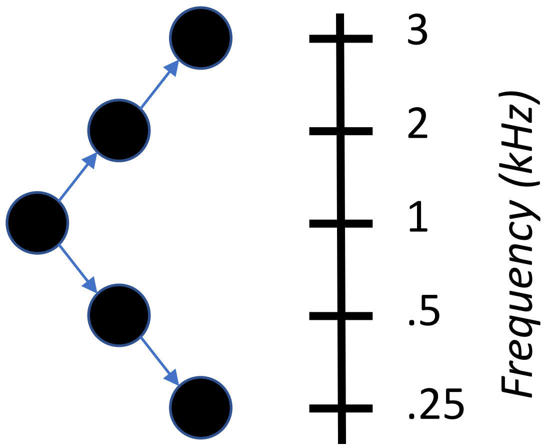


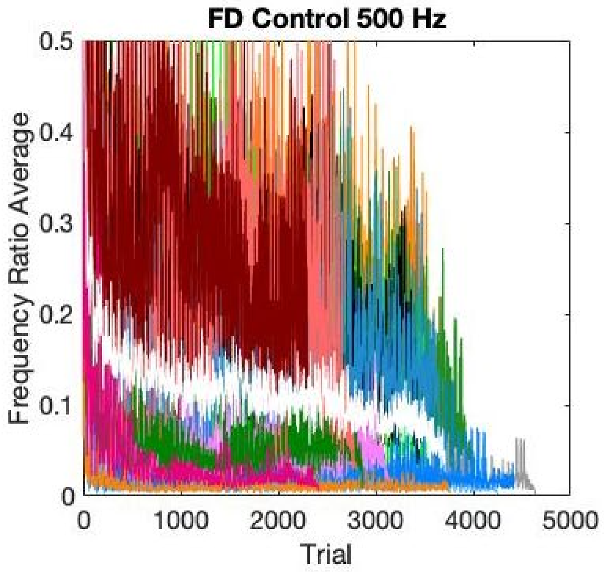
Up/Down Frequency Discrimination (Control)

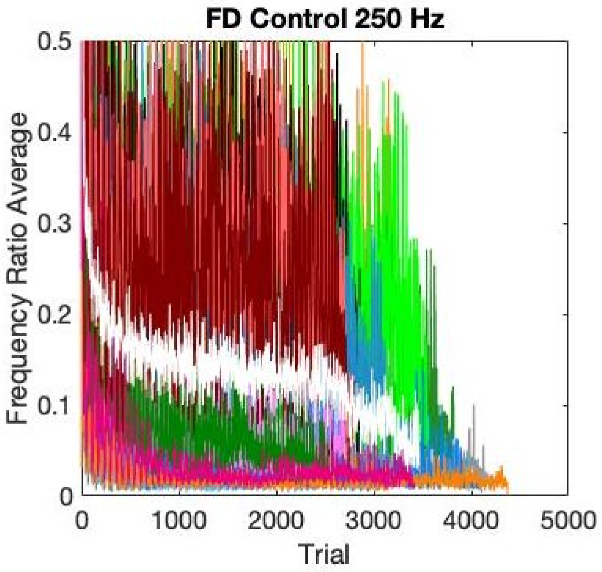






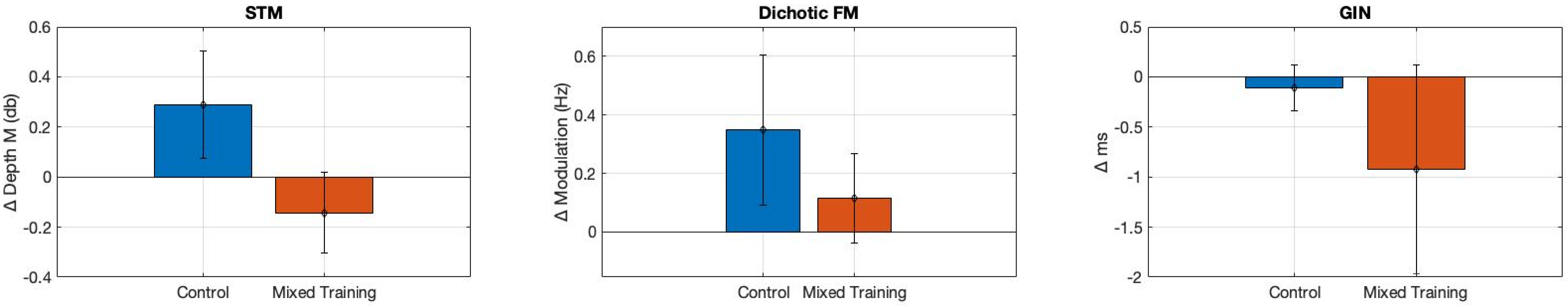




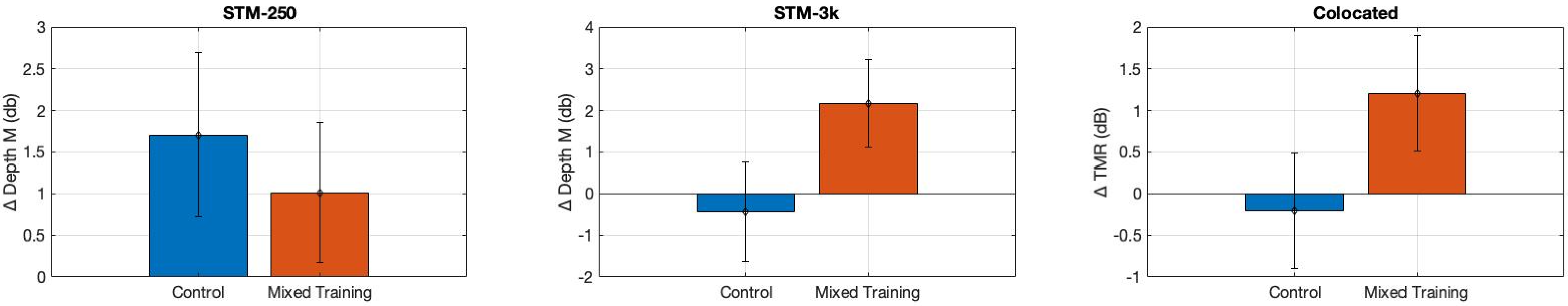


Even in the control condition, learning continued for the entire length of training.

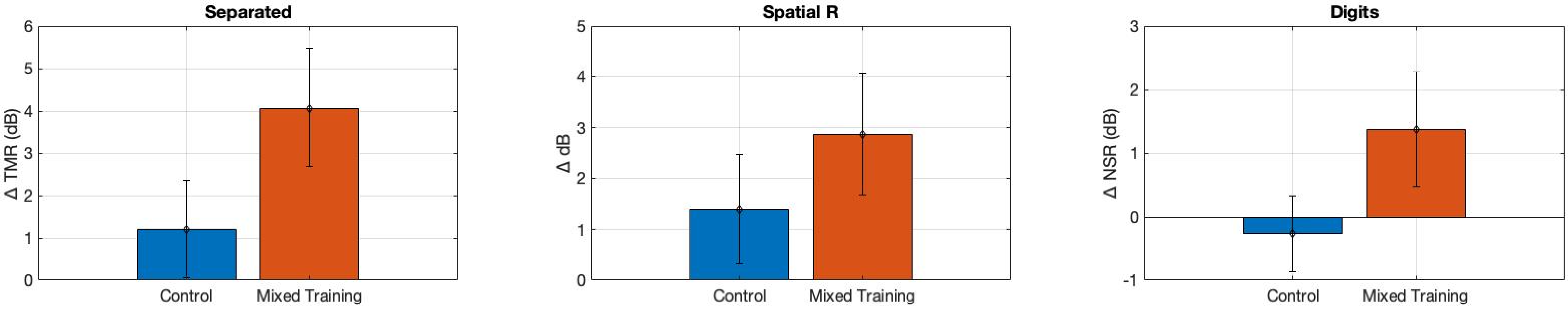
Change in Performance after Training



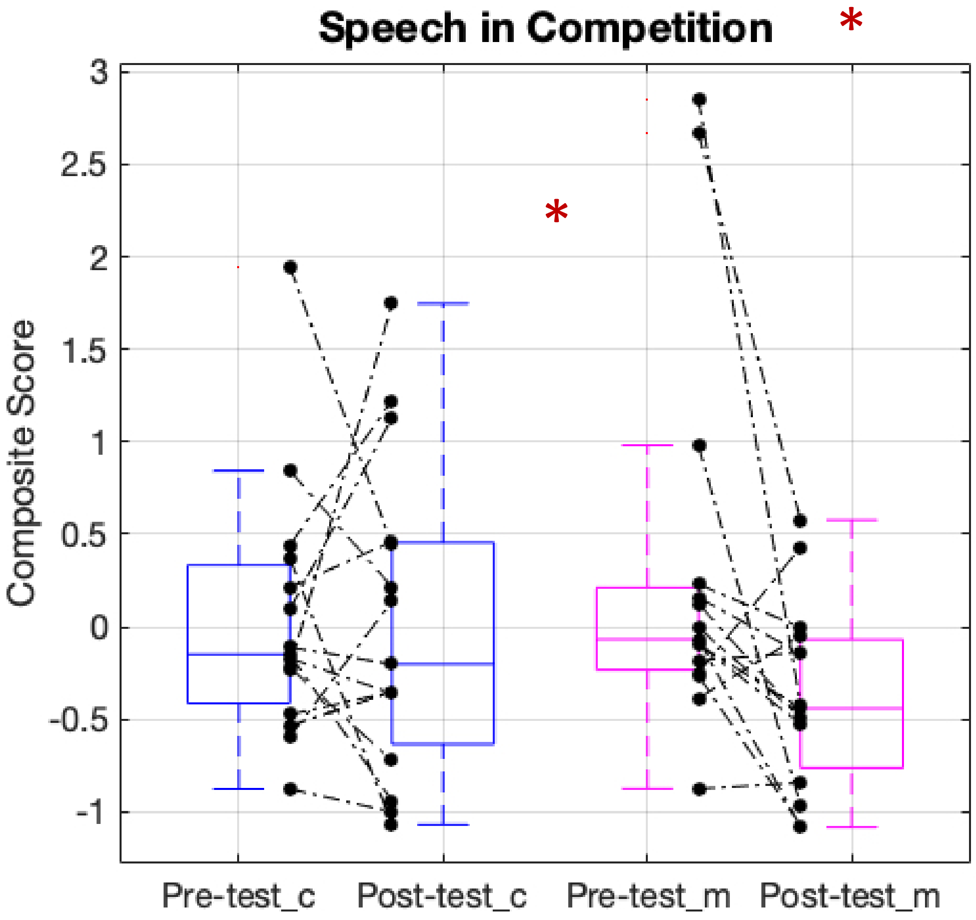
Change in Performance after Training

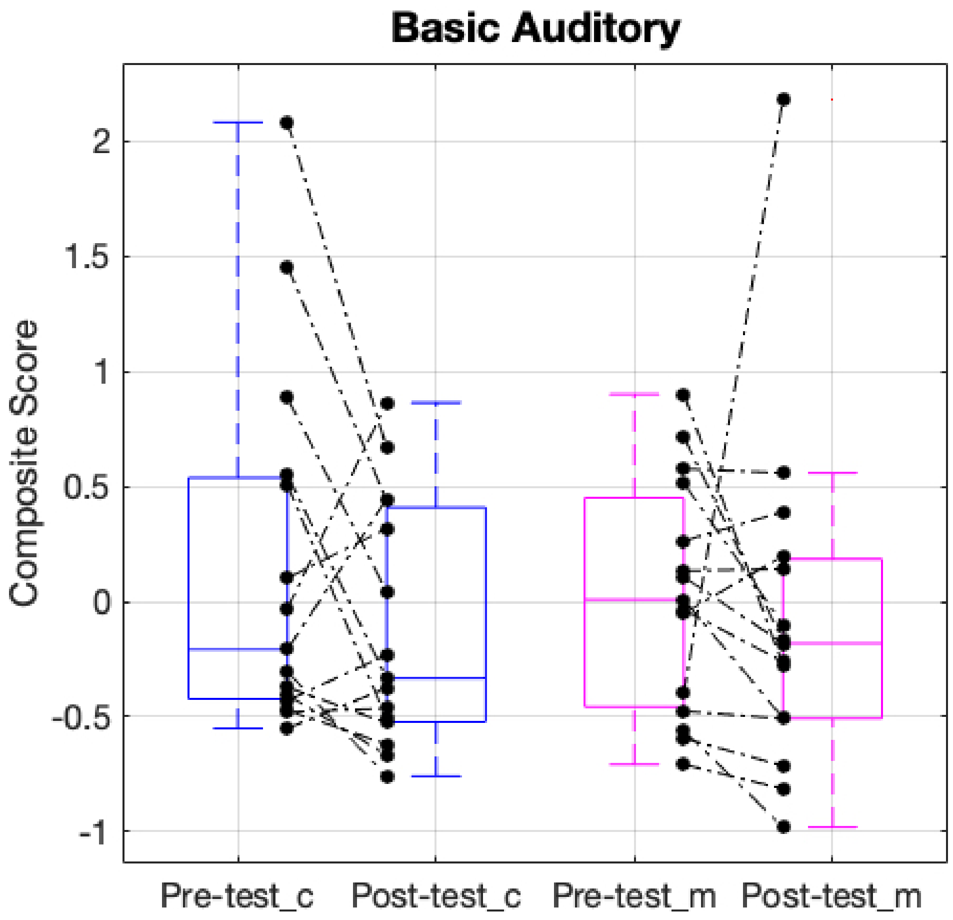


Change in Performance after Training



Change in Performance after Training





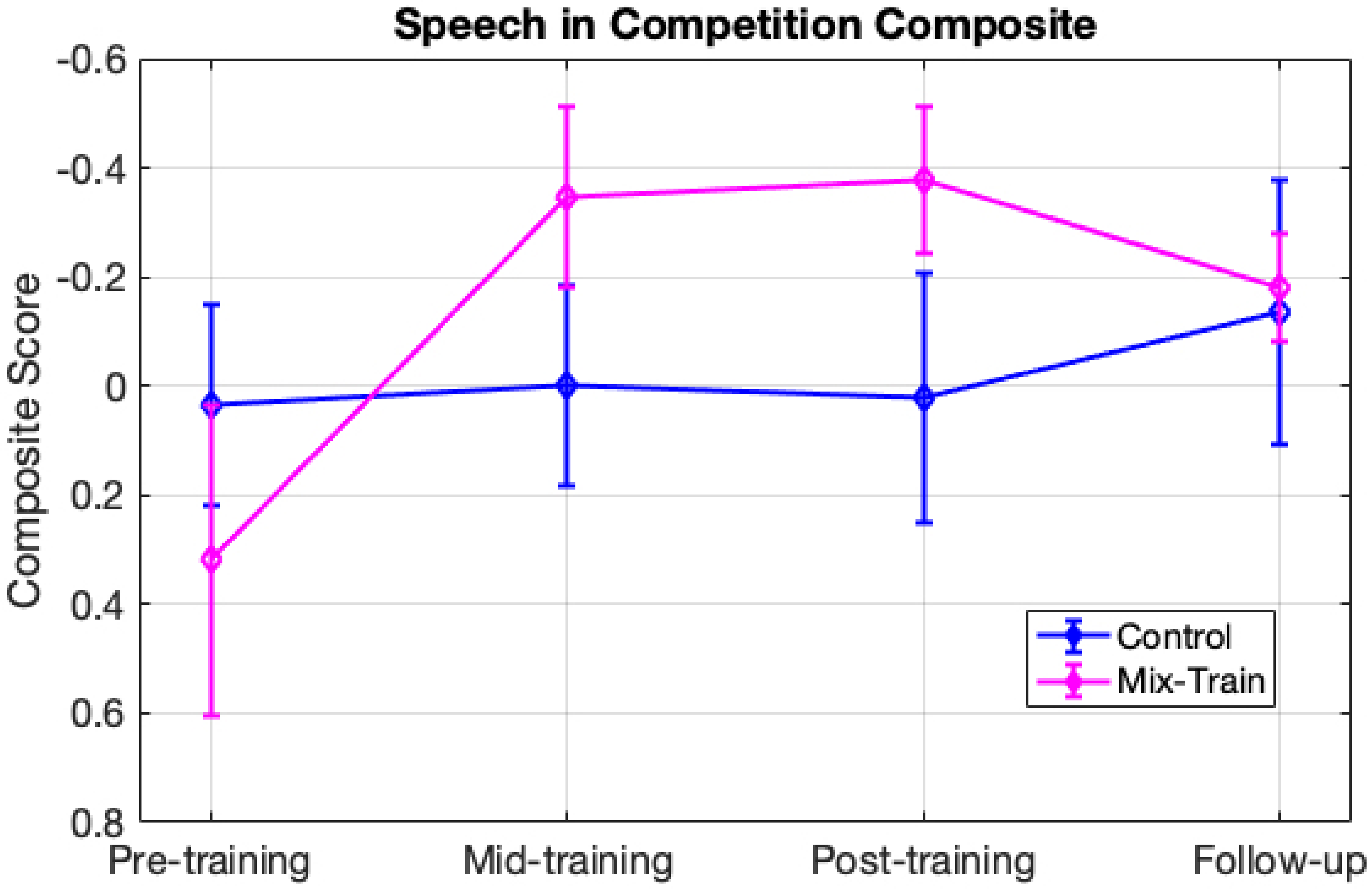
Differences (between)

$t_{(28)} = -1.91$, $p = 0.03$*, *Cohen's d* = -0.68

Differences (between)

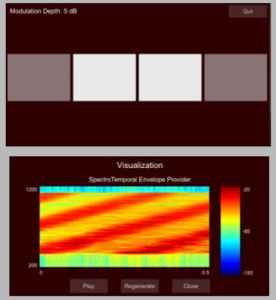
$t_{(28)} = 0.63$, $p = 0.27$, *Cohen's d* = 0.22

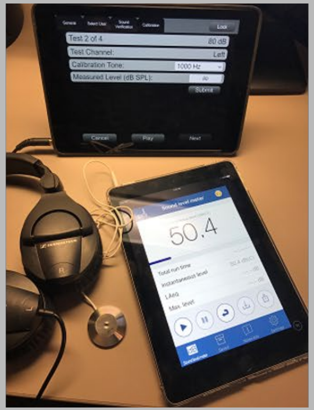
Change in Performance after Training

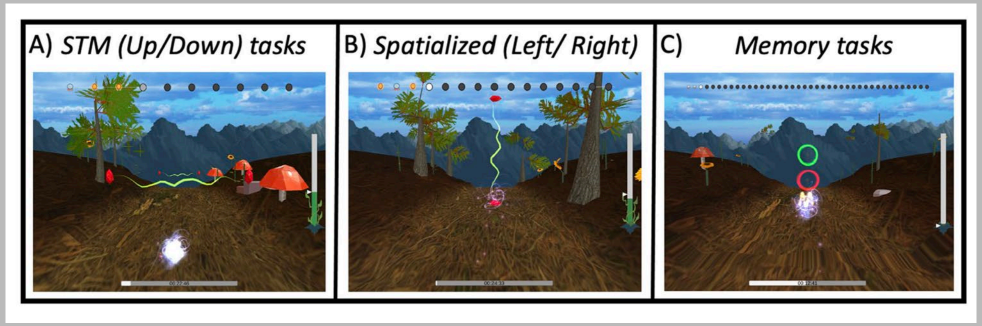


- Amount of Training
  - Learning effect is not different at mid-test ($t_{(14)} = -0.25$, $p = 0.8$, *Cohen's d* = -0.06)
- Retention
  - No learning effect remains by follow-up ($t_{(28)} = -0.96$, $p = 0.17$, *Cohen's d* = -0.34)

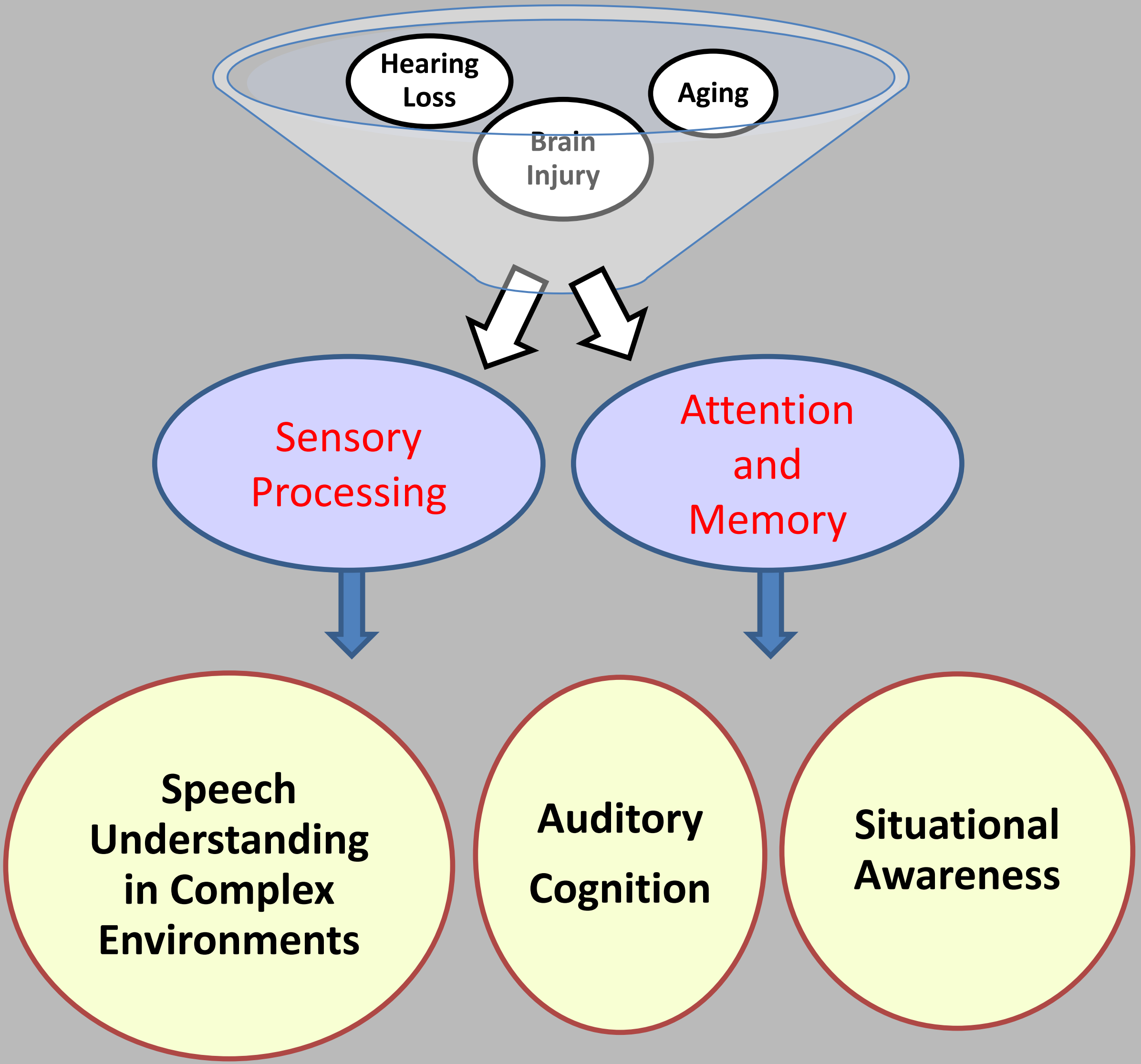
PART and Listen are free for download: https://bgc.ucr.edu
https://braingamecenter.ucr.edu/games/listen-an-auditory-training-experience/
https://braingamecenter.ucr.edu/games/p-a-r-t/







Thank you for your attention!



Clinical Tests Sensitive to Auditory Dysfunction in Patients with Confirmed Injury to Auditory Cortex

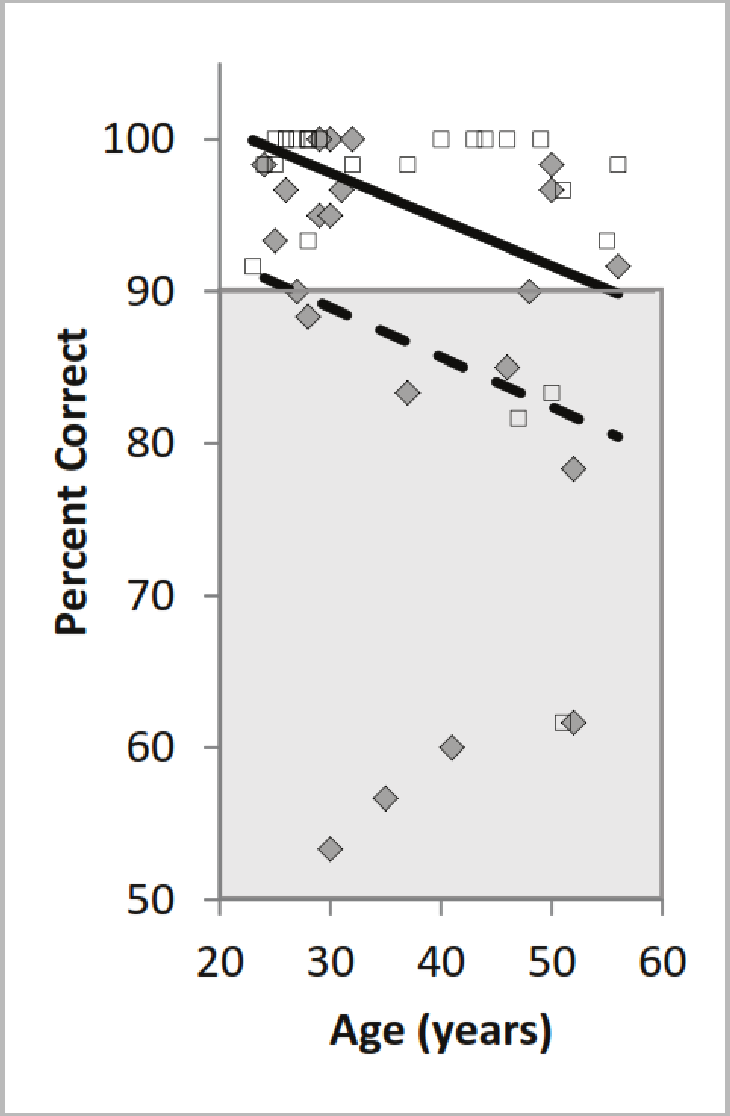
Test	% Abnormal
MLD: Masking Level Difference[1]	30%
FP: Frequency Patterns[2]	83%
GIN: Gaps-in-Noise[3]	78%
SSW: Staggered Spondaic Words[4]	69%
DD: Dichotic Digits[4]	45%

1: Jabbari et al. (1987) *Auditory brainstem response findings in the late phase of head injury.* Semin Hear, **8**(3)

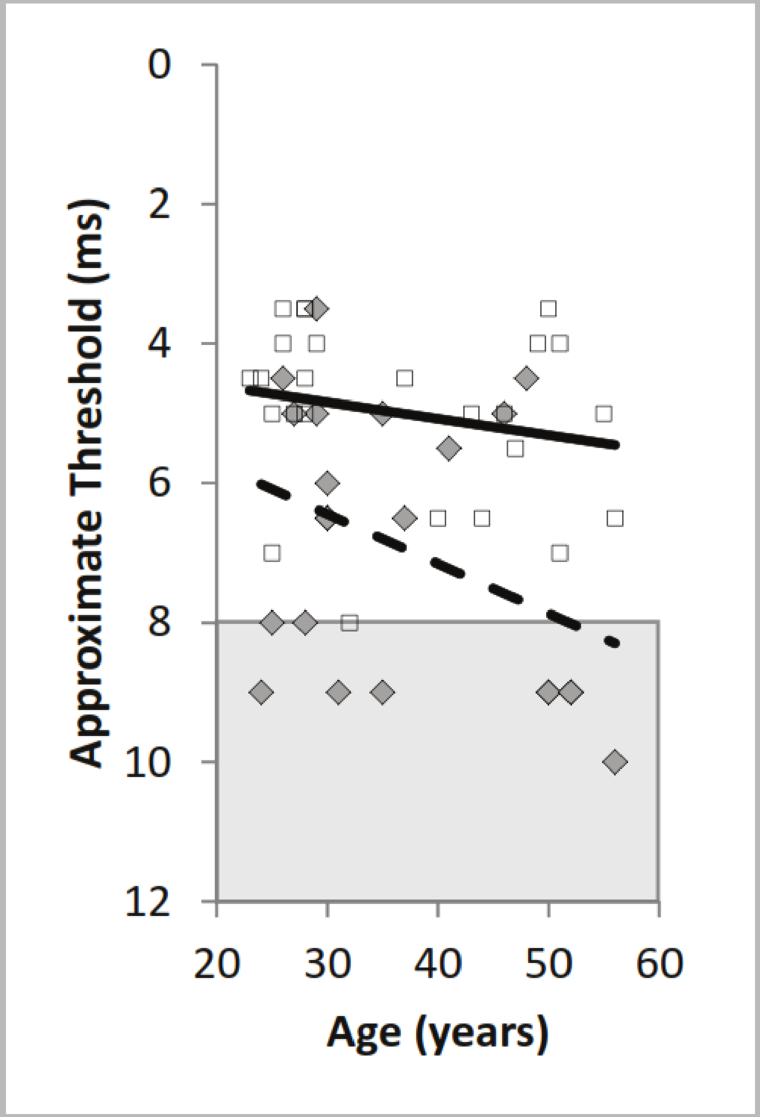
2: Musiek and Pinheiro (1987) *Frequency patterns in cochlear, brainstem, and cerebral lesions.* Audiology, **26**(2)

3: Musiek et al. (2005) *GIN (Gaps-In-Noise) test performance in subjects with confirmed central auditory nervous system involvement.* Ear Hear, **26**(6)

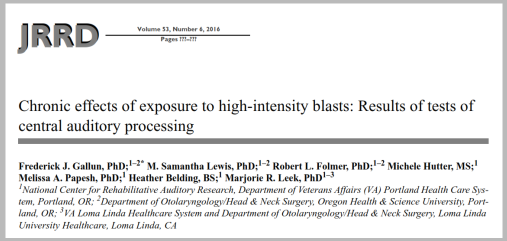
4: Mueller et al. (1987) *Comparison of the Efficiency of Cortical Level Speech Tests.* Semin Hear, **8**(3)



Frequency Patterns Test



Gaps In Noise



JRRD
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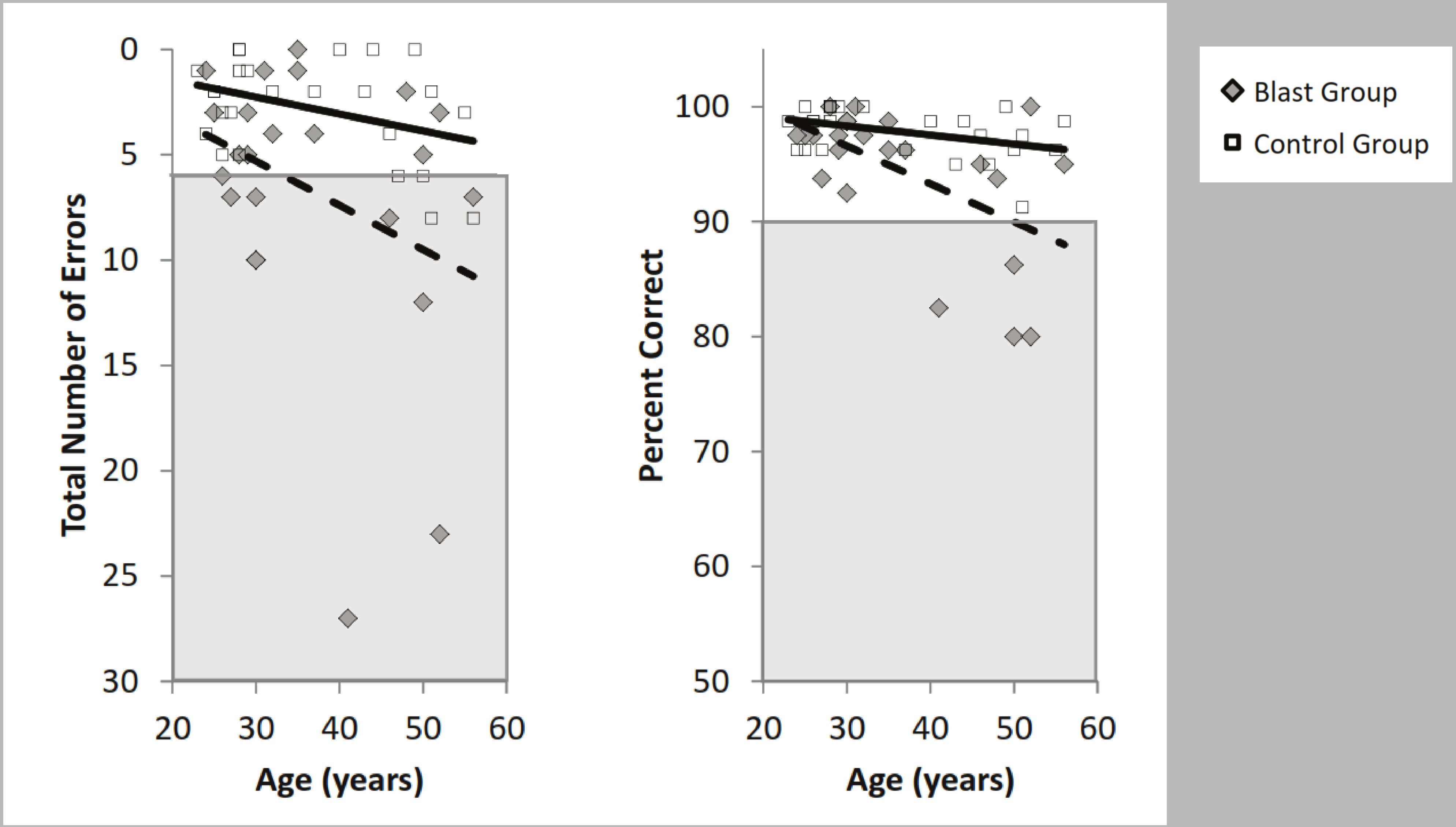
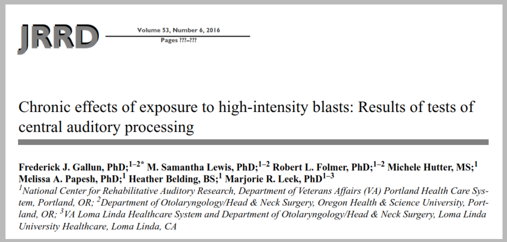
Chronic effects of exposure to high-intensity blasts: Results of tests of central auditory processing

Frederick J. Gallun, PhD;[1–2*] M. Samantha Lewis, PhD;[1–2] Robert L. Folmer, PhD;[1–2] Michele Hutter, MS;[1] Melissa A. Papesh, PhD;[1] Heather Belding, BS;[1] Marjorie R. Leek, PhD[1–3]
[1]National Center for Rehabilitative Auditory Research, Department of Veterans Affairs (VA) Portland Health Care System, Portland, OR; [2]Department of Otolaryngology/Head & Neck Surgery, Oregon Health & Science University, Portland, OR; [3]VA Loma Linda Healthcare System and Department of Otolaryngology/Head & Neck Surgery, Loma Linda University Healthcare, Loma Linda, CA



Staggered Spondaic Words

Dichotic Digits



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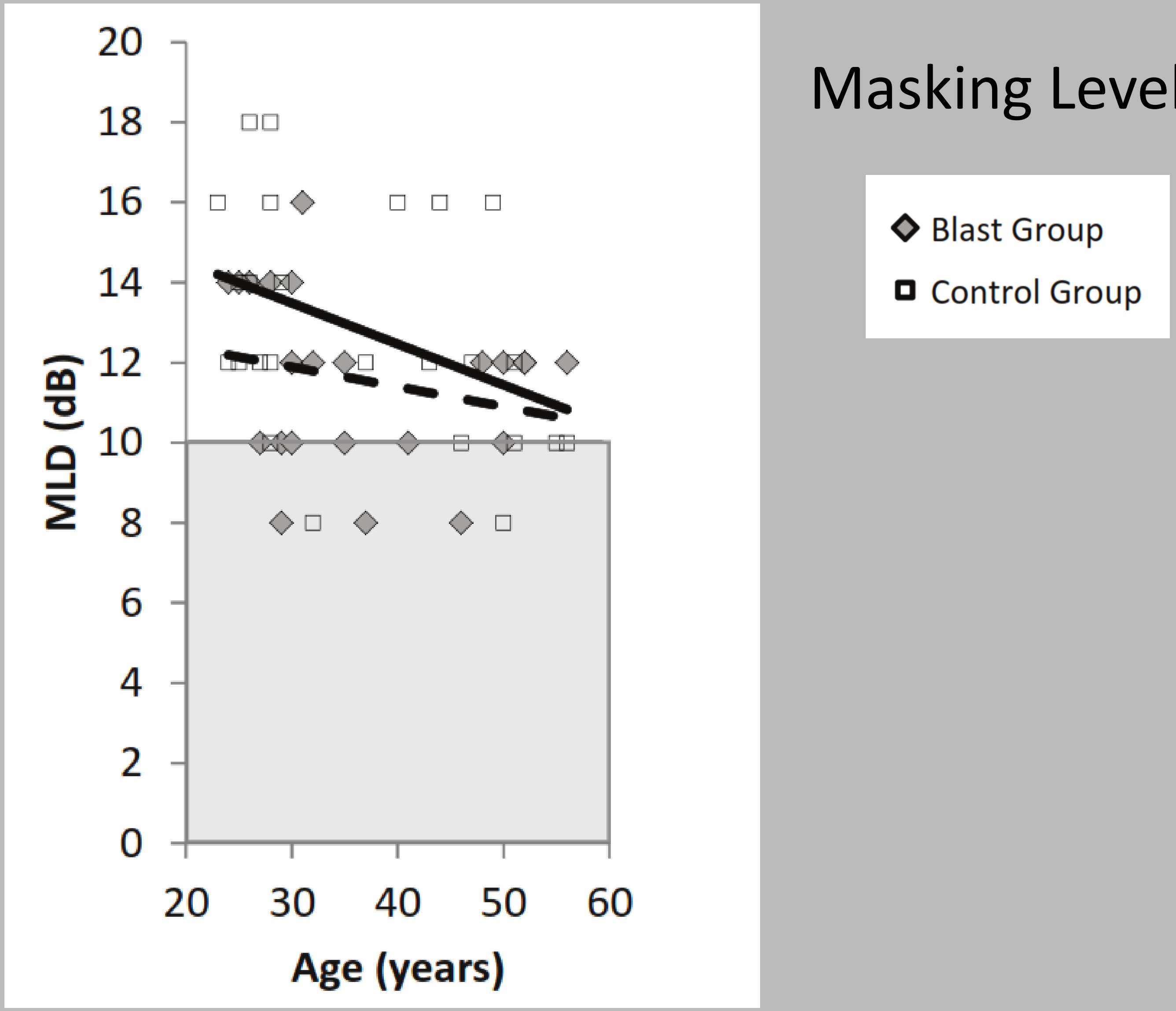
Masking Level Differences



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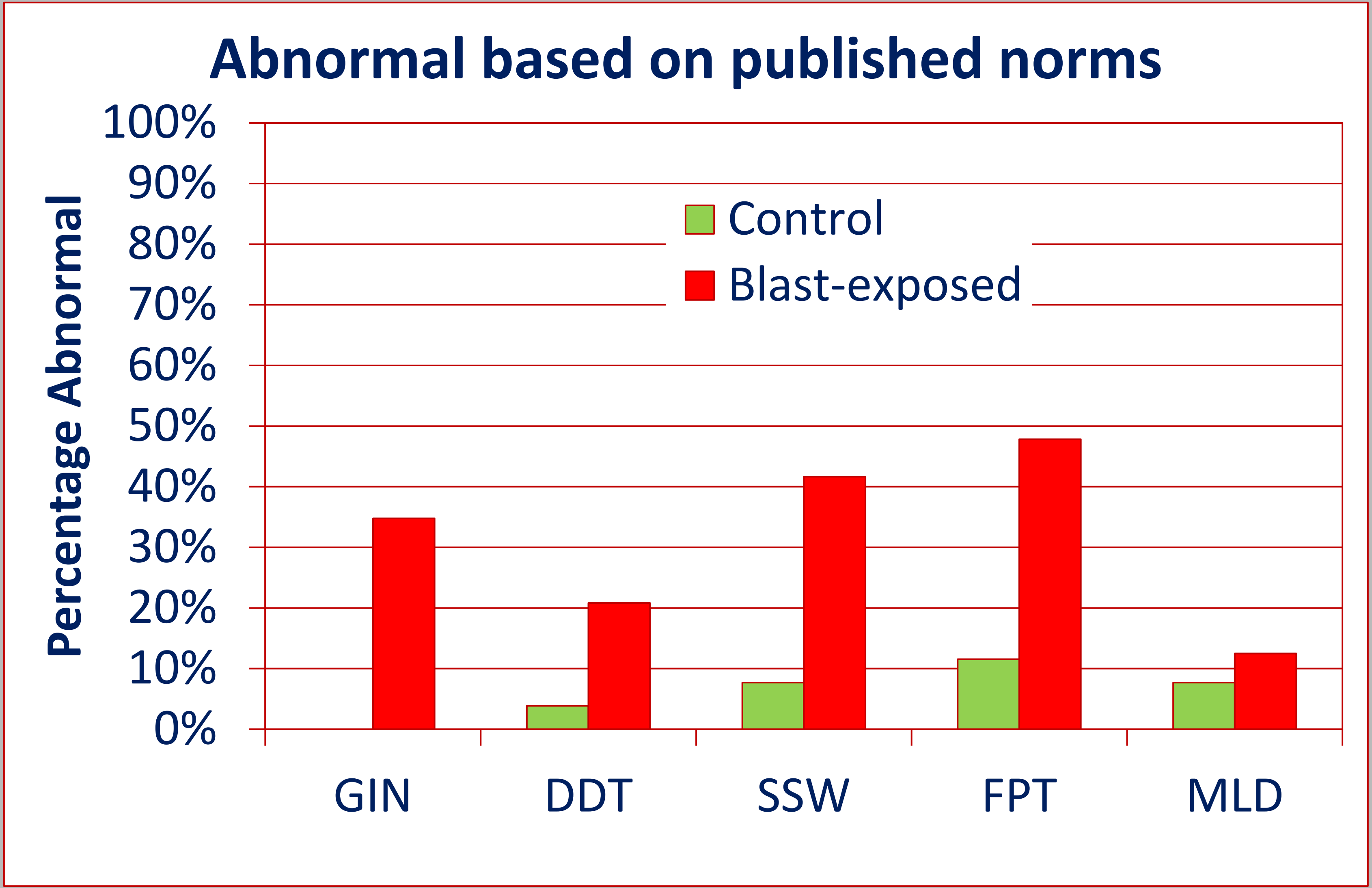

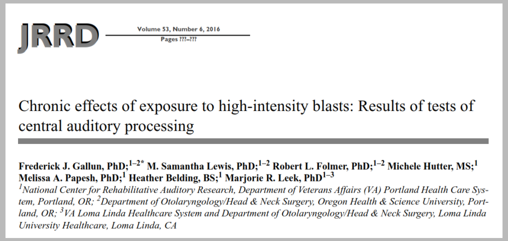

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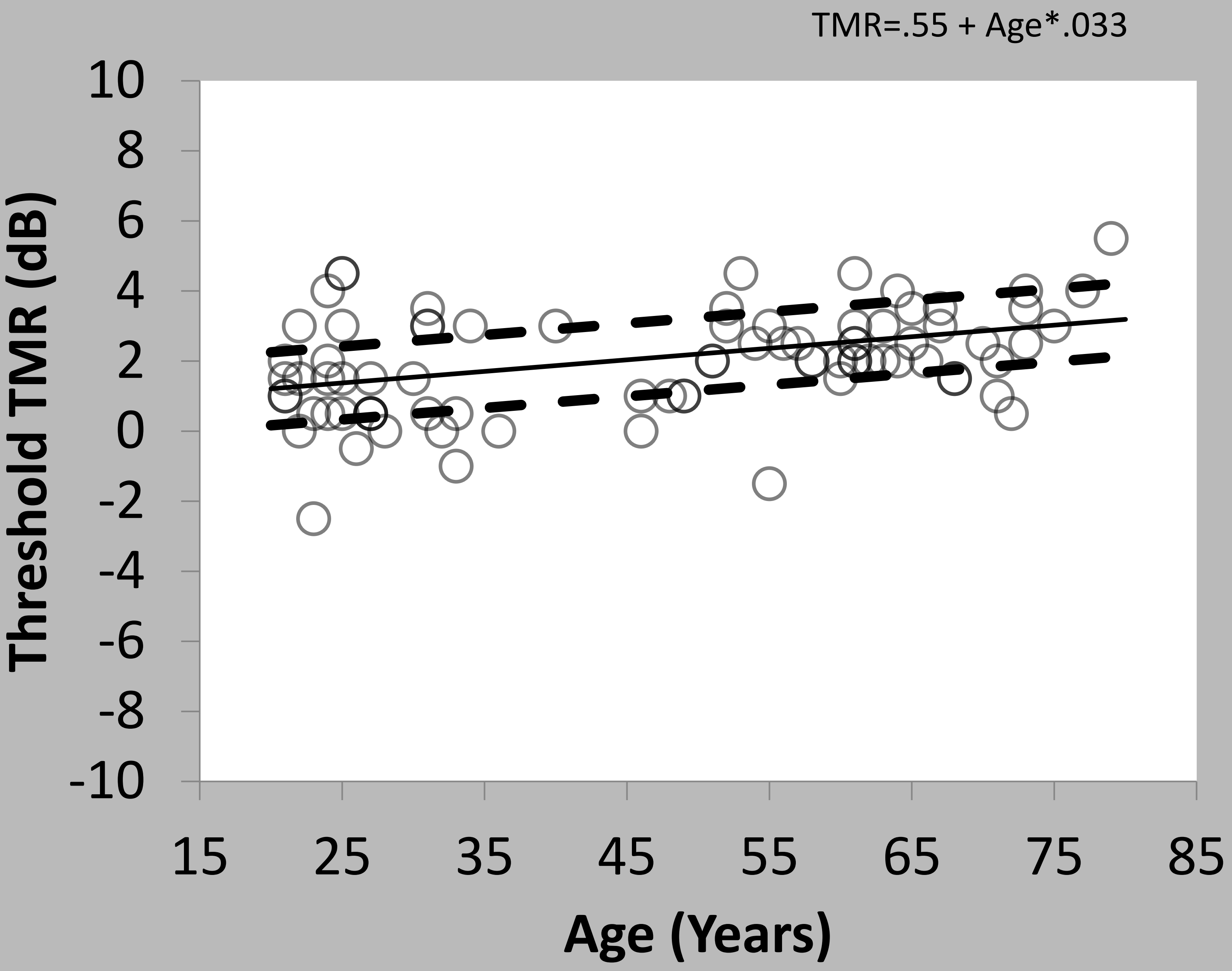
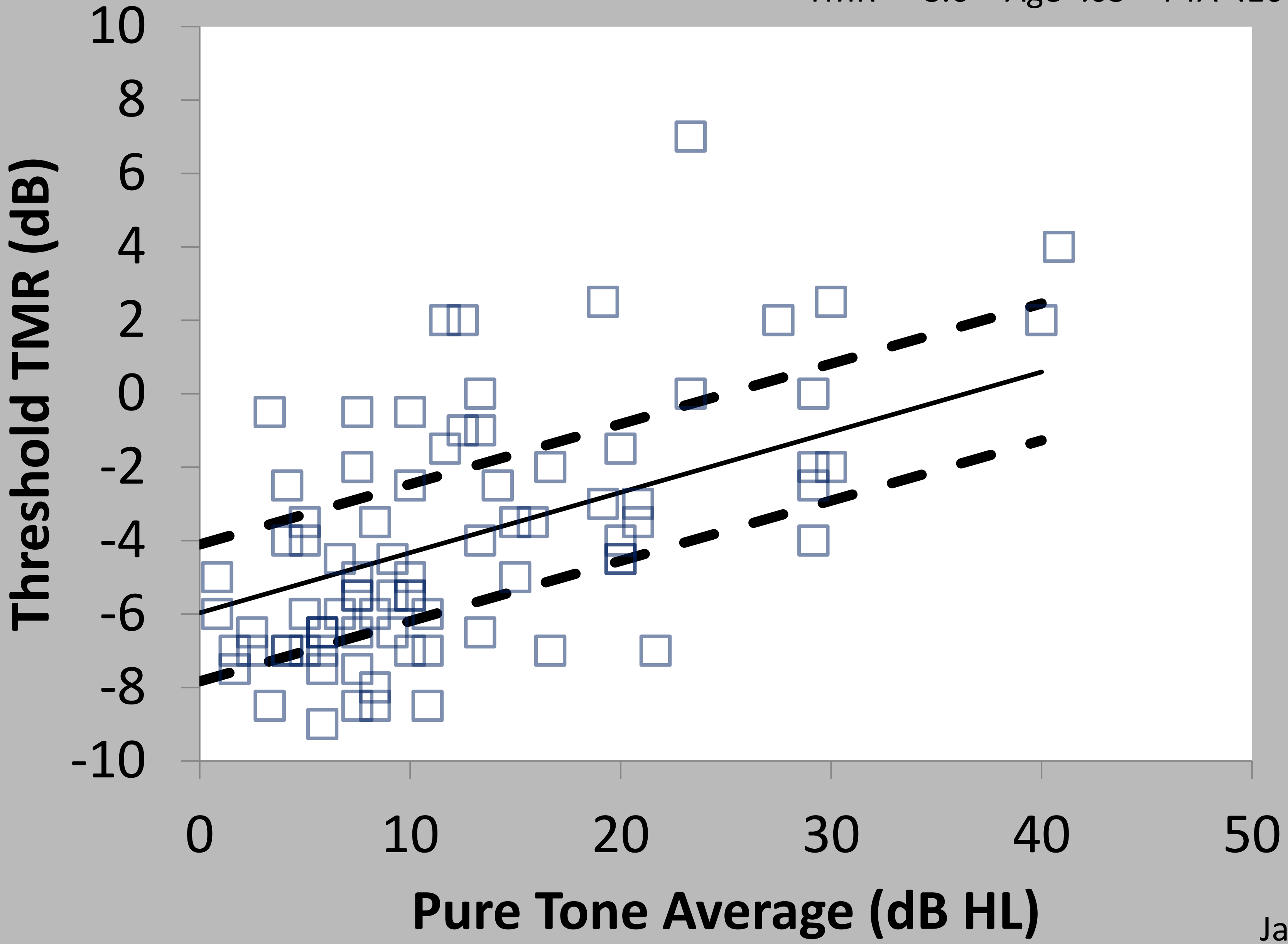
Normative Date: Colocated



Jakien and Gallun (2018)

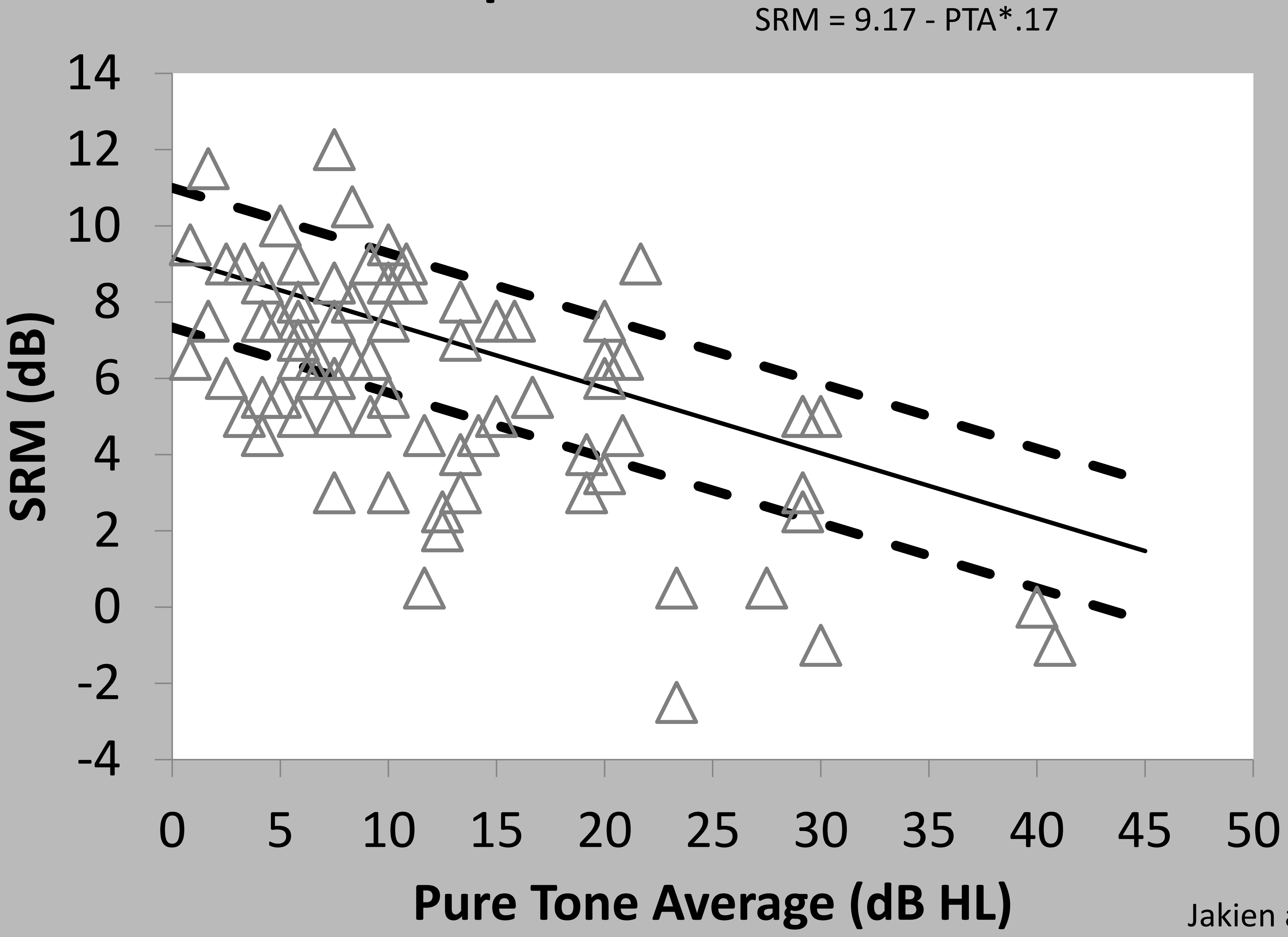
Normative Date: Separated (45 degrees)

TMR = -8.6 + Age*.05 + PTA*.16



Jakien and Gallun (2018)

Normative Date: Spatial Release



Jakien and Gallun (2018)