Describing, diagnosing, and treating auditory processing abilities and disabilities in adults

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The opinions expressed do not necessarily reflect the positions or policies of the government of the United States of America

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Dept. of Veterans Affairs

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Spinal Cord Injury
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(Baltimore, MD)

Agenda

1. Auditory processing abilities in adults: Motivation from Veterans with exposure to high-intensity blasts
2. Research next steps: Portable Automated Rapid Testing (PART)
3. Auditory neuroscience: Functions of the Central Auditory System
4. Psychoacoustical testing using PART
5. Next steps in testing: Informational masking
6. Rehabilitation: The promise of auditory brain training

PART 1

Auditory processing abilities in adults

Motivation from Veterans with exposure to high-intensity blasts

Blast Exposure and Traumatic Brain Injury (TBI)

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

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)

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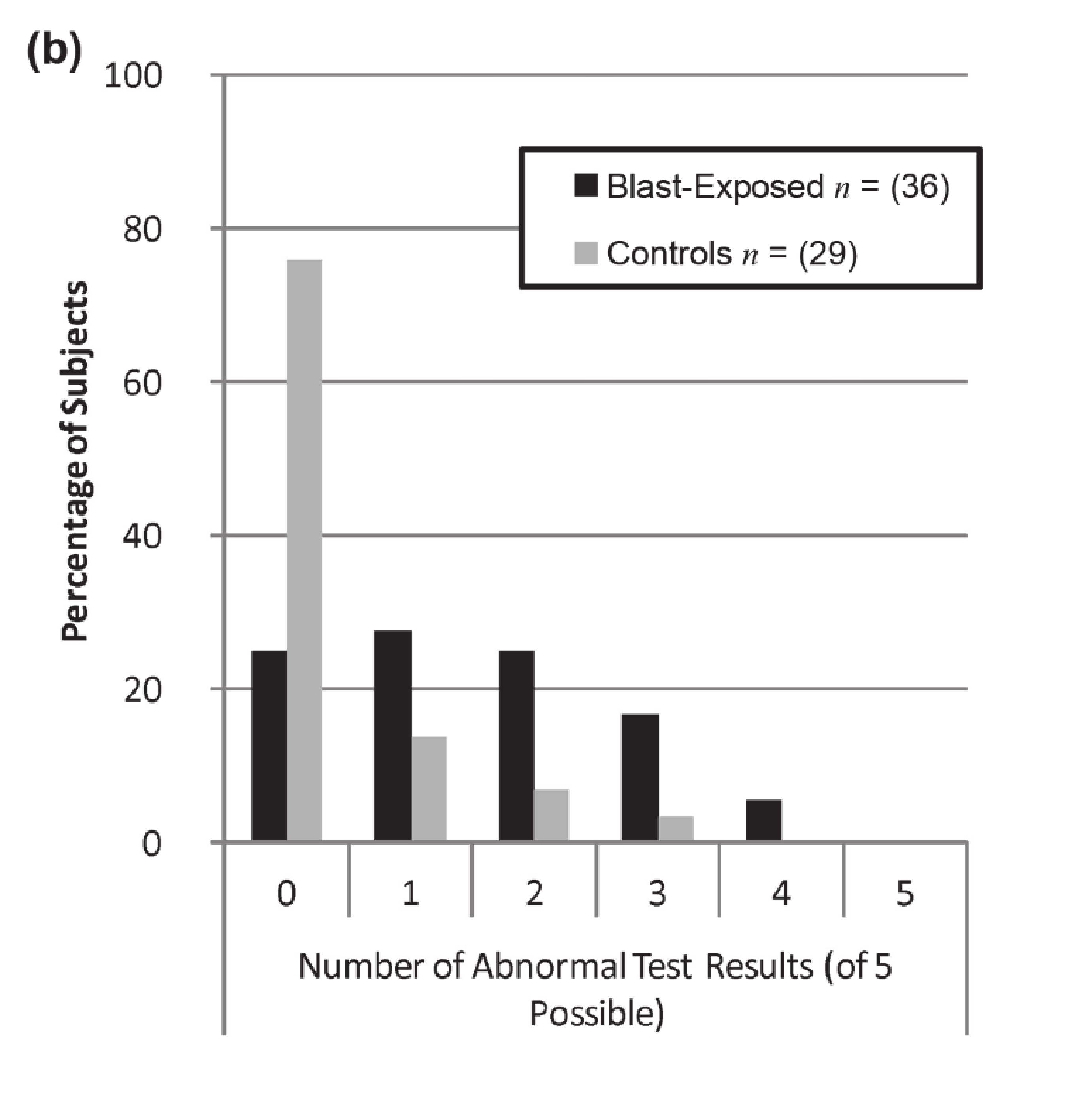
Pages 1005–1024

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

Frederick J. Gallun, PhD;[1–2*] Anna C. Diedesch, AuD;[1] Lina R. Kubli, MS;[3] Therese C. Walden, AuD;[3] Robert L. Folmer, PhD;[1–2] M. Samantha Lewis, PhD;[1–2] Daniel J. McDermott, MS;[1] Stephen A. Fausti, PhD;[1–2] Marjorie R. Leek, PhD[1–2]
[1]National Center for Rehabilitative Auditory Research (NCRAR), Portland Department of Veterans Affairs Medical Center, Portland, OR; [2]Oregon Health & Science University, Portland, OR; [3]Audiology and Speech Center, Scientific and Clinical Studies Section, Walter Reed National Military Medical Center, Bethesda, MD

- Blast exposed service members tested at Walter Reed within one year of exposure
- Control group with same age and pure tone thresholds as blast group



Proportion abnormal on **one or more** behavioral test of Central Auditory Processing:

Control: 24%

Blast: 75%

JRRD
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Pages ???–???

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

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

  Mean age: **37.3 years** (sd 11.5)

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

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

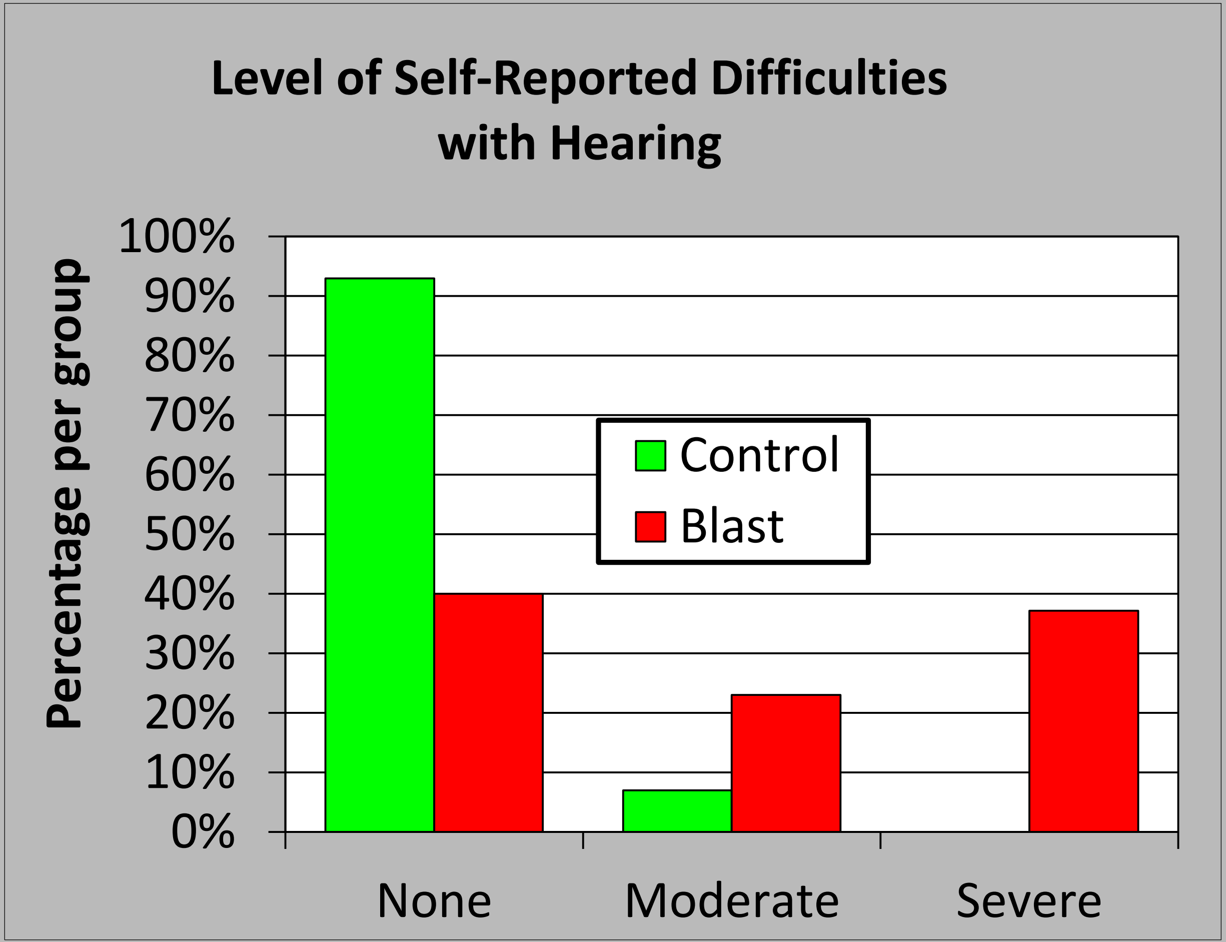
  Number with PTSD Diagnosis: **23/30**

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

  Mean age: **39.5 years** (sd 13.9) Number with PTSD Diagnosis: **4/29**

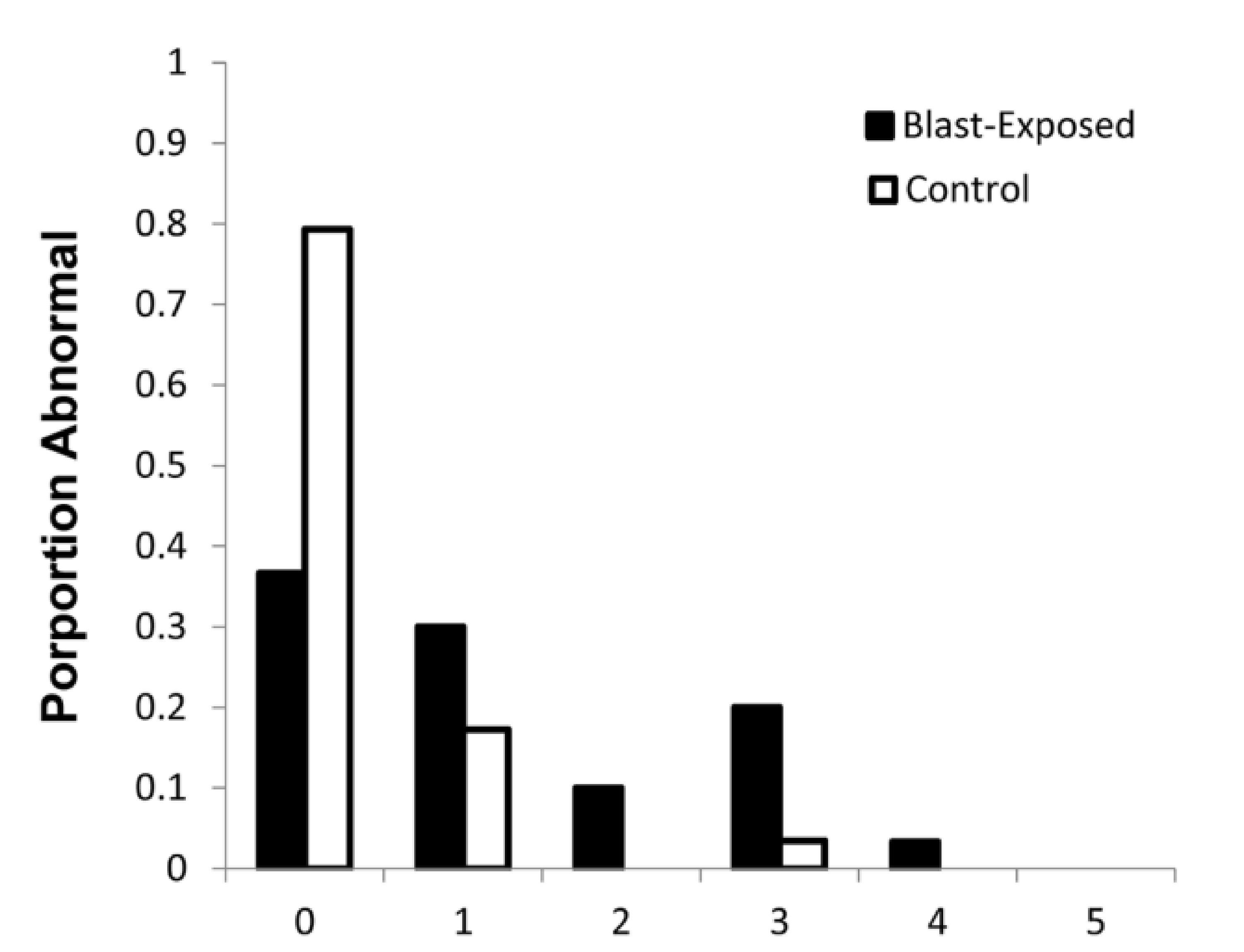
Self-Report: Hearing Handicap Inventory – Adult

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



60% of blast-exposed report moderate or severe hearing handicap

Number of Tests with Abnormal Performance



Tests abnormal (out of 5 possible)

Percent abnormal on one or more test:

Control (n=29): 21%

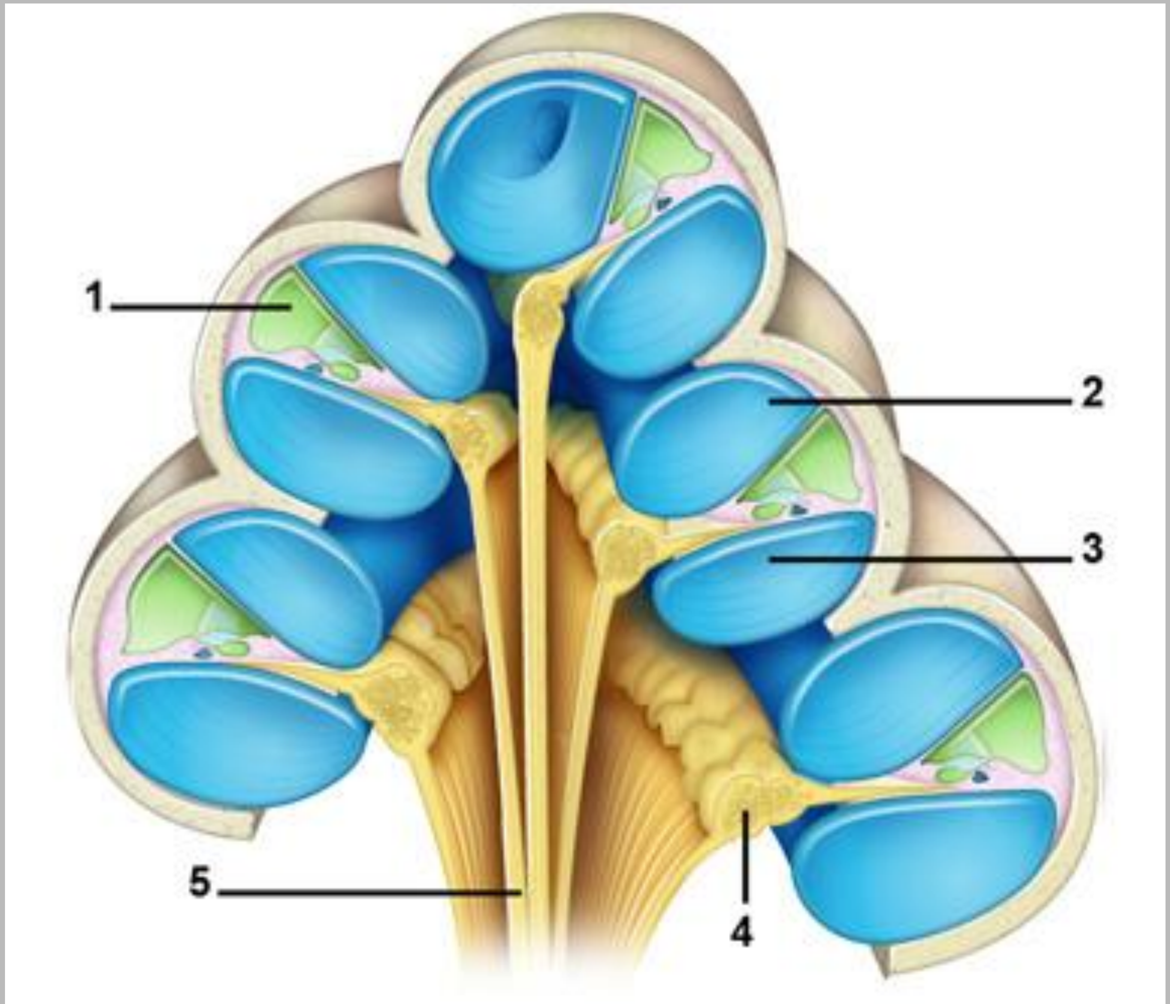
Blast (n=30) : 63%

Where could these deficits come from?

Auditory nerve

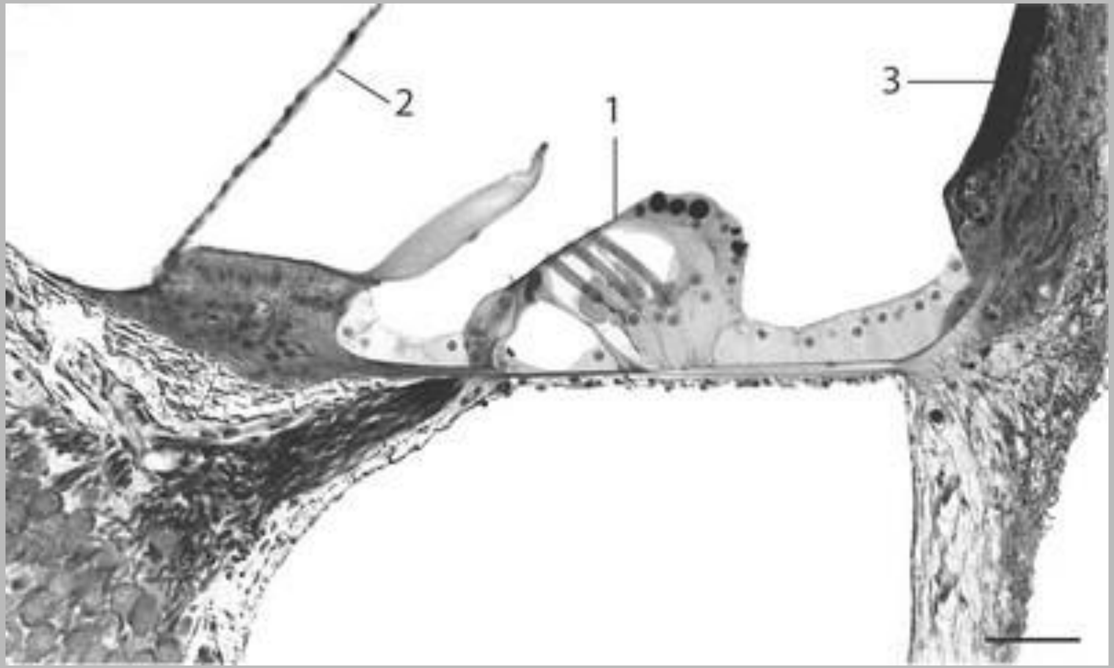
Brainstem

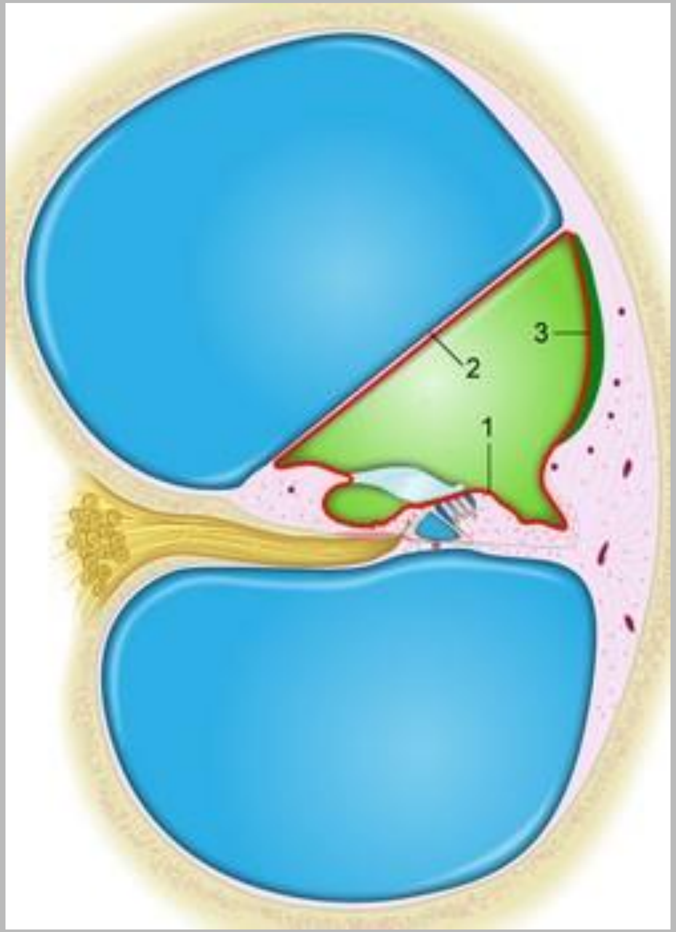
Cortex



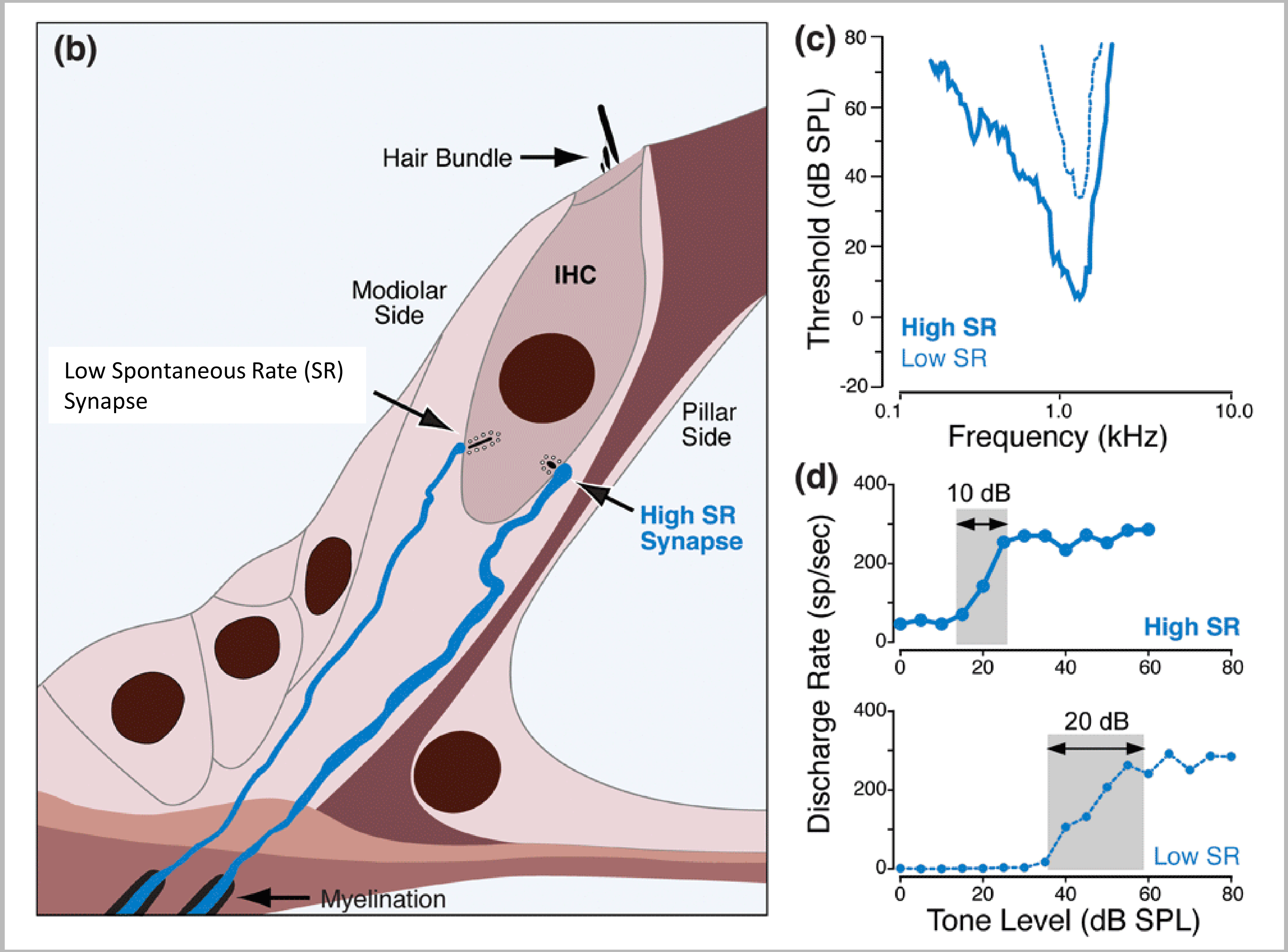
1. scala media
2. scala vestibuli
3. scala tympani
4. spiral ganglion neurons
5. auditory nerve

http://www.cochlea.eu/en/

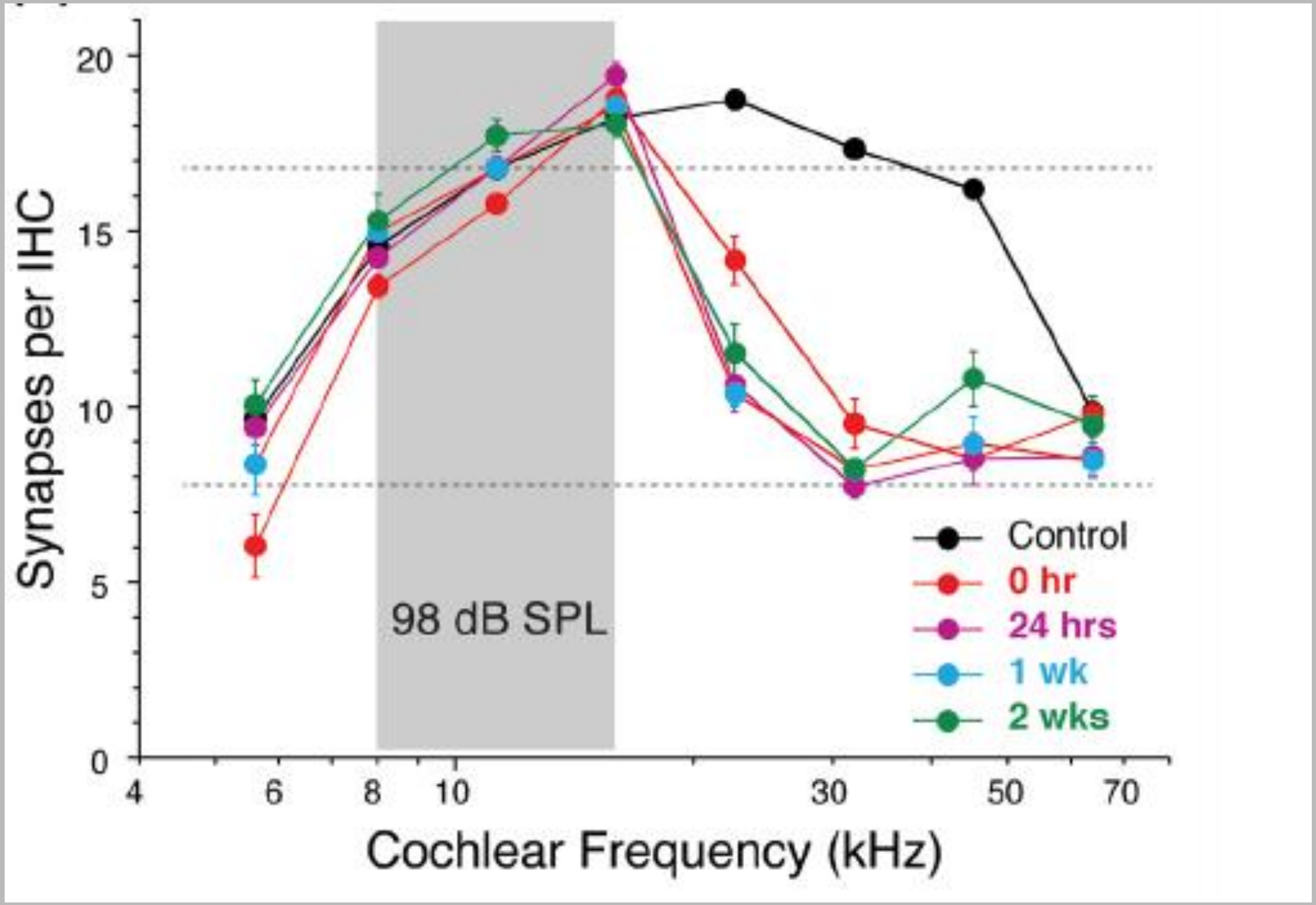




1. Organ of Corti
2. Reissner’s Membrane
3. lateral wall



Liberman, M. C. (2017). Noise-induced and age-related hearing loss: new perspectives and potential therapies. *F1000Research*, *6*.

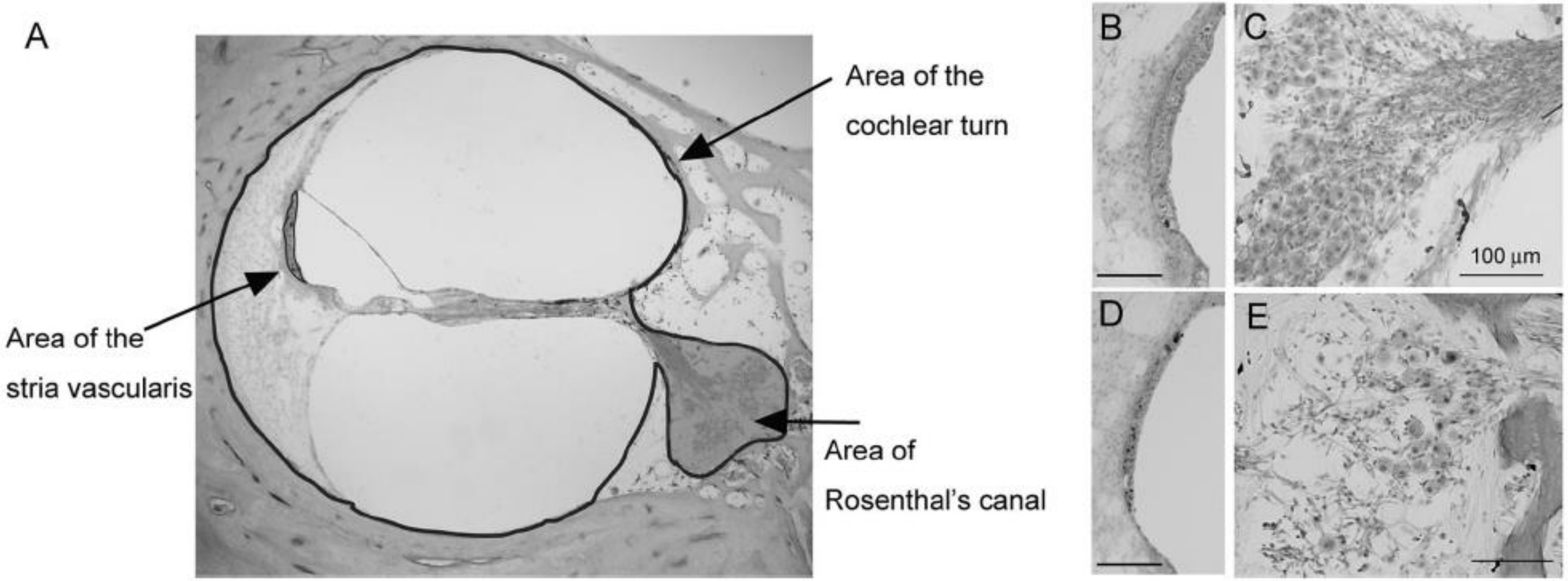


In the mouse, exposure to 98 dB SPL noise destroys synapses, despite a return of threshold detectability to baseline levels.

It is unknown whether or not blast exposure involves synapse destruction.

There is currently no agreed upon method by which to detect such damage behaviorally.

Liberman, M. C. (2017). Noise-induced and age-related hearing loss: new perspectives and potential therapies. *F1000Research*, *6*.



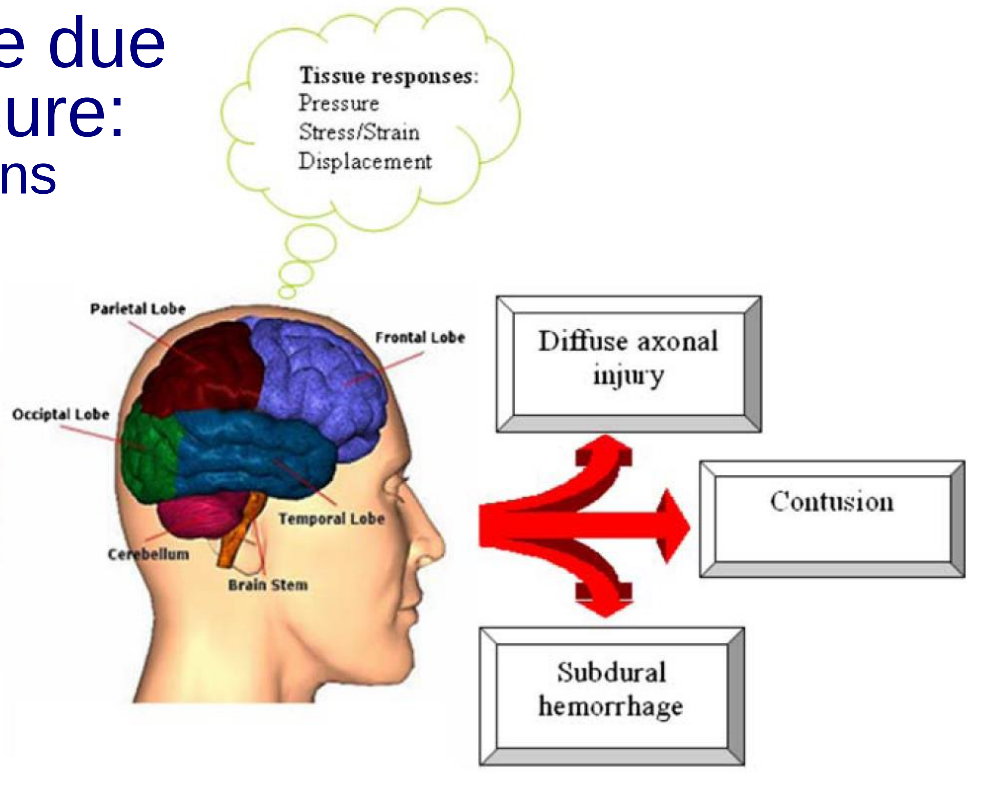
Younger

Older

Fig. 1. Morphology of human cochleae. (A) Basal turn of cochlea of 38-year-old male. Area of cochlear turn (black line). Area of SV (dotted line). Area of Rosenthal's canal (gray section). (B) Stria vascularis (SV) of 19-year-old male showing no atrophic changes. (C) Spiral ganglion (SG) of a 37-year-old female exhibiting numerous neurons. (D) SV of 79-year-old male, which is more atrophic than that shown in B. (E) SG of a 77-year-old female, which shows relatively few neurons. Scale bars = 100 μm.

Laryngoscope 116: October 2006 Suzuki et al.: Age-Related Changes in Human Cochleae

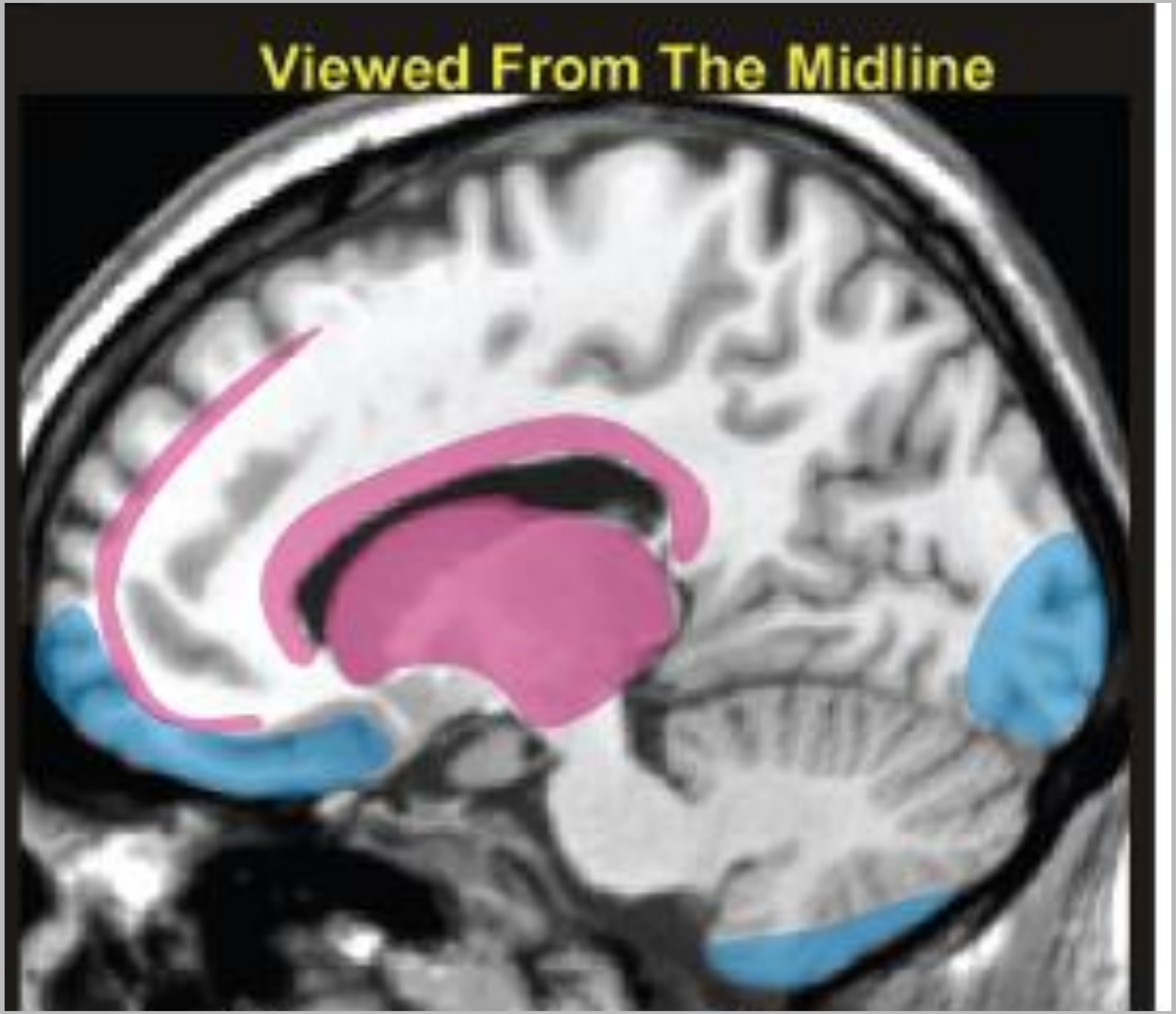
Central Damage due to Blast Exposure:
Model Predictions



- injury to axons (stretching and shearing of axons)
- bruising of the brain surface (contusion)
- internal bleeding (subdural hemorrhage) from ruptured blood vessels

Chafi et al (2010) Biomechanical assessment of brain dynamic responses due to blast pressure waves. *Annals of Biomedical Engineering.* 38(2)

Potential for Damage to Auditory Brain Areas:
Primary Mechanism: Blast Pressure Wave from Explosion



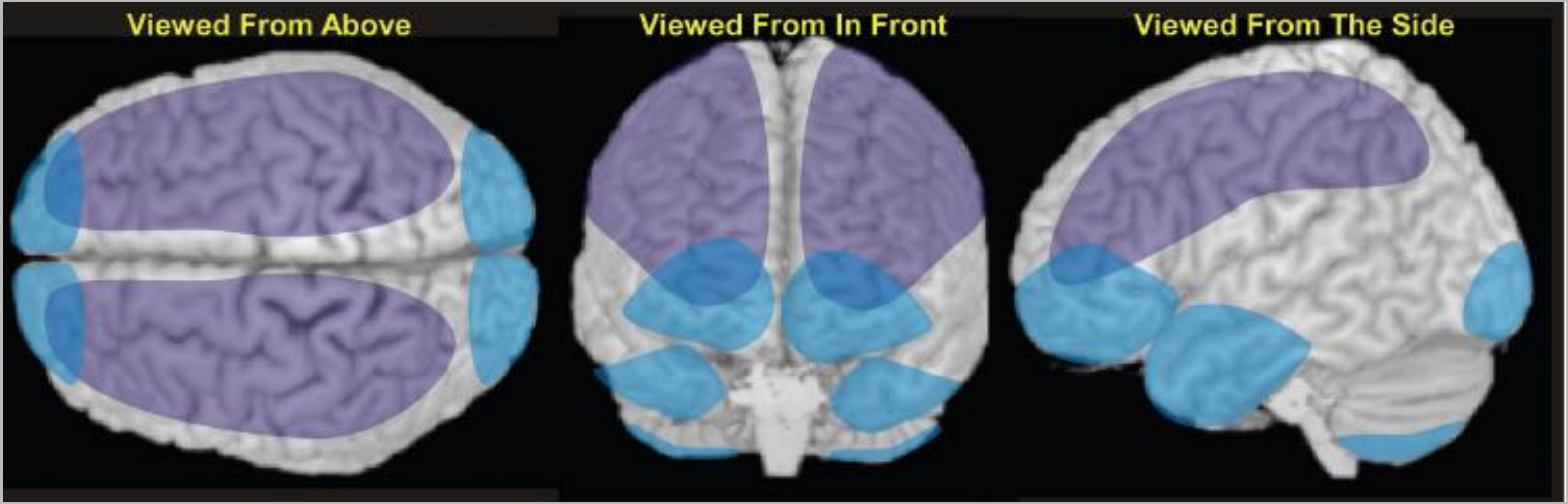
Stretching or shearing of thalamus and corpus callosum connections resulting in disconnection of inputs or cell death.

Contusions: blue
Diffuse axonal injury: pink

Taber et al., 2006

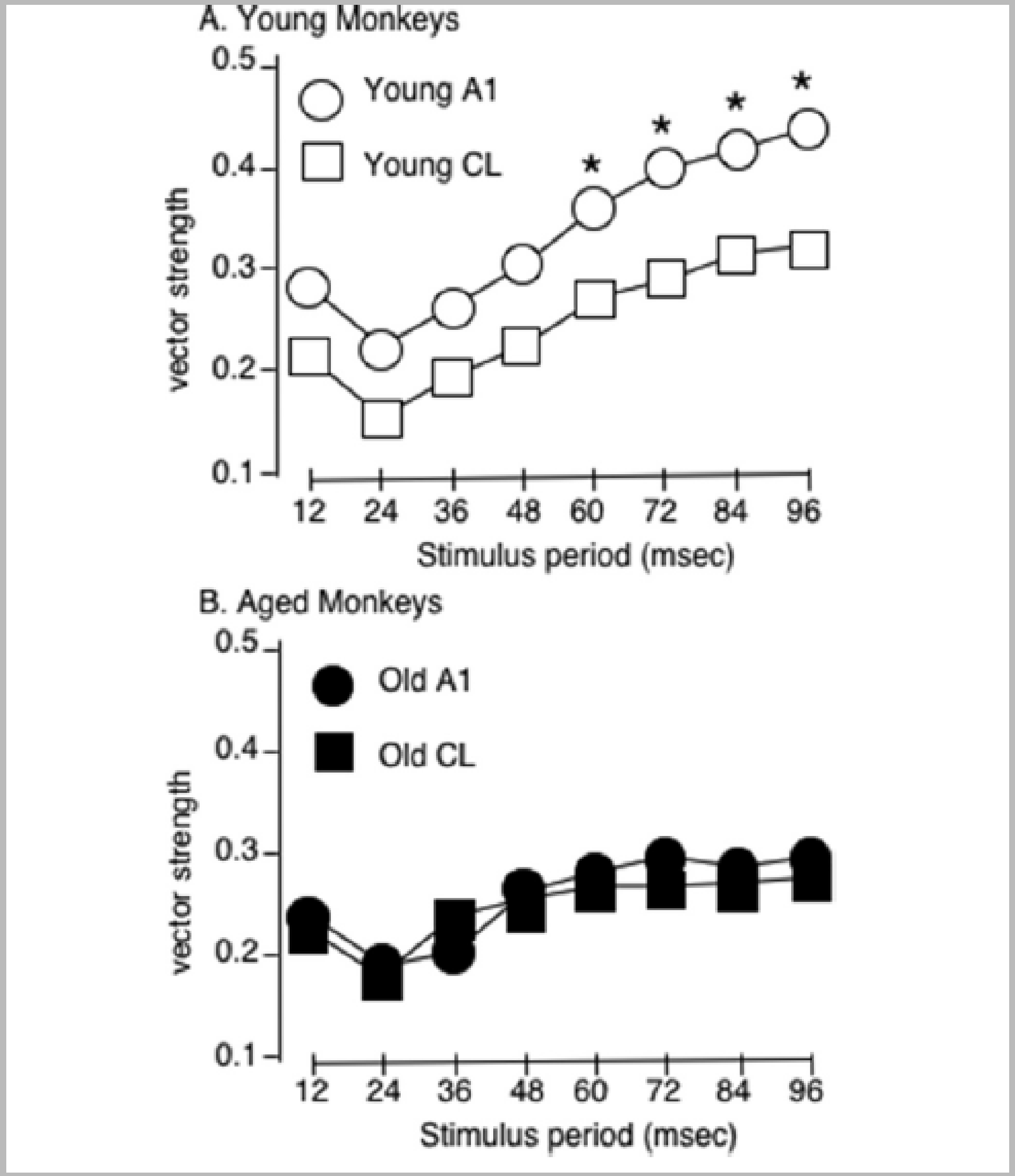
Damage to Auditory Brain Areas:
II. Secondary and Tertiary Mechanisms: Blunt Head Trauma, Penetrations

- Contusions to temporal and frontal lobes (blue)
- Hemorrhage damage to frontal and parietal lobes (purple)



Taber et al., 2006

Neurophysiological data from younger (Panel A) and older (Panel B) monkeys. Younger and older monkeys had similar temporal encoding in CL (a brain area associated with auditory spatial processing), but phase locking was reduced in A1 (“primary auditory cortex”) for older monkeys.



Recanzone (2018).

PART 2

Auditory processing abilities in adults

Next steps from a research perspective

How can we know whether or not these areas have been damaged?

There is no “gold standard”, because in almost all cases, a diagnosis of mild TBI implies that there is no injury visible with any of the common clinical imaging techniques.

Instead, we have to use behavioral and electrophysiological tests and compare to normative data. However, those norms are often lacking for people who are middle aged or older, especially if they have hearing loss.

Furthermore, many of the tests described in the previous slides are hard to do for people with attention and memory issues, or if they have language problems.

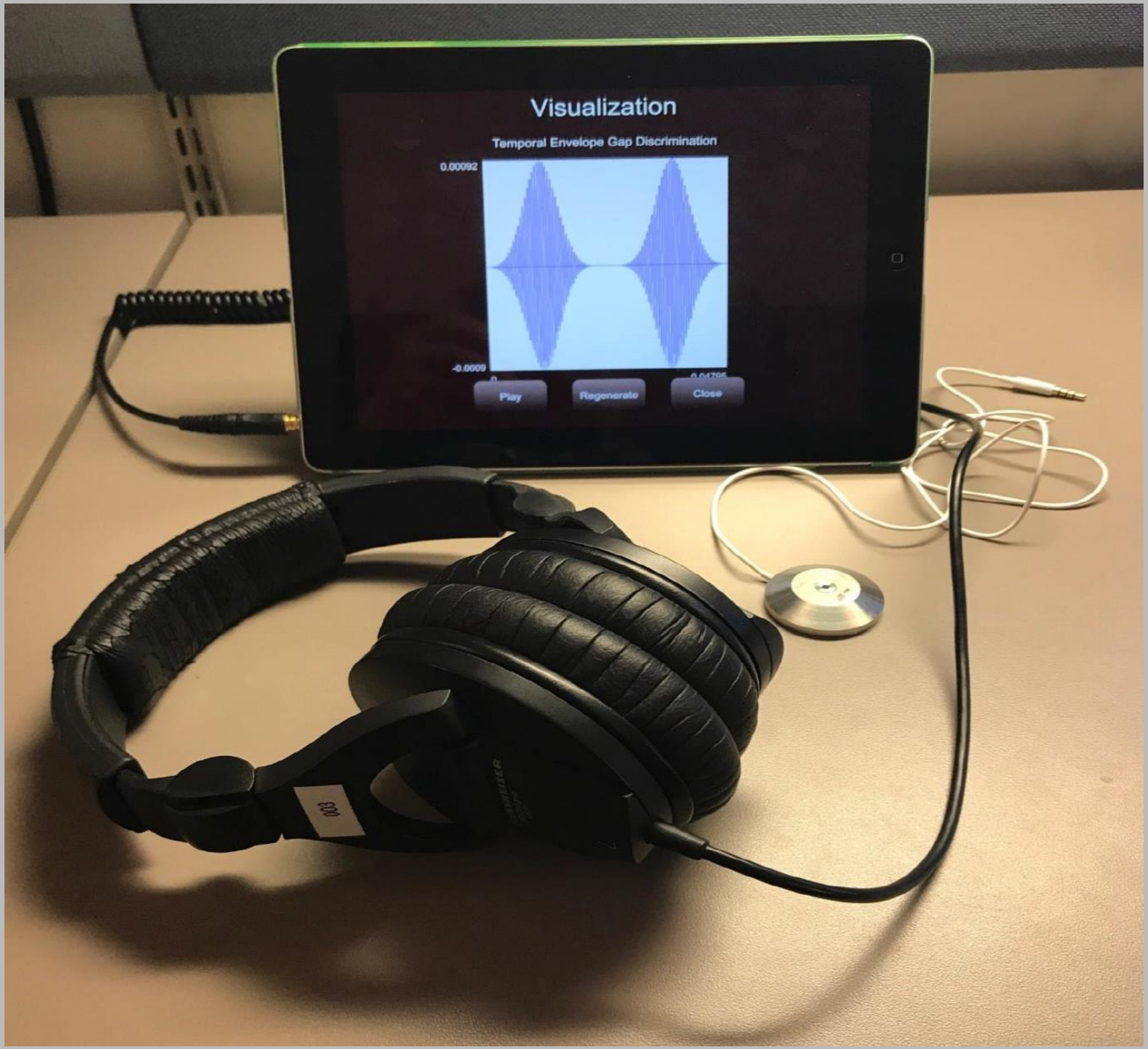
All of these are common in people with mTBI, and especially common in the deployed Veteran population.

To address these issues, we believe it is important to first establish whether or not basic auditory processing abilities are affected. We have looked to modern neuroscience to define what we mean by fundamental auditory processing abilities.

To this end, we have, with the support of NIH, developed a software platform for psychoacoustics that is free, runs on an iPad with inexpensive headphones, and is based on current auditory neuroscience and psychoacoustics.

With this platform we hope to establish norms for people varying in age and hearing ability that can be used to determine whether or not an individual is within the normal range. This can then be used to identify deficits which can then guide further treatment and be used as a marker of recovery.

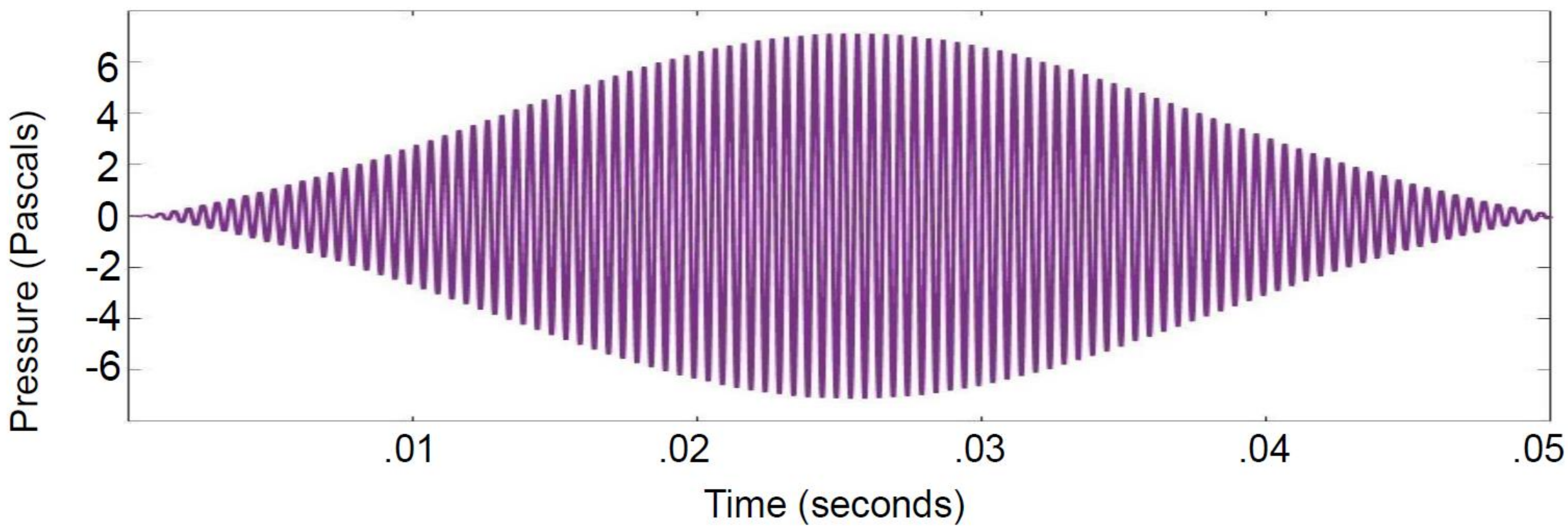
Some patients are expected to have no deficits on any of these tests and so any complaints or difficulties found on other tests can then be attributed to factors other than basic auditory processing abilities.

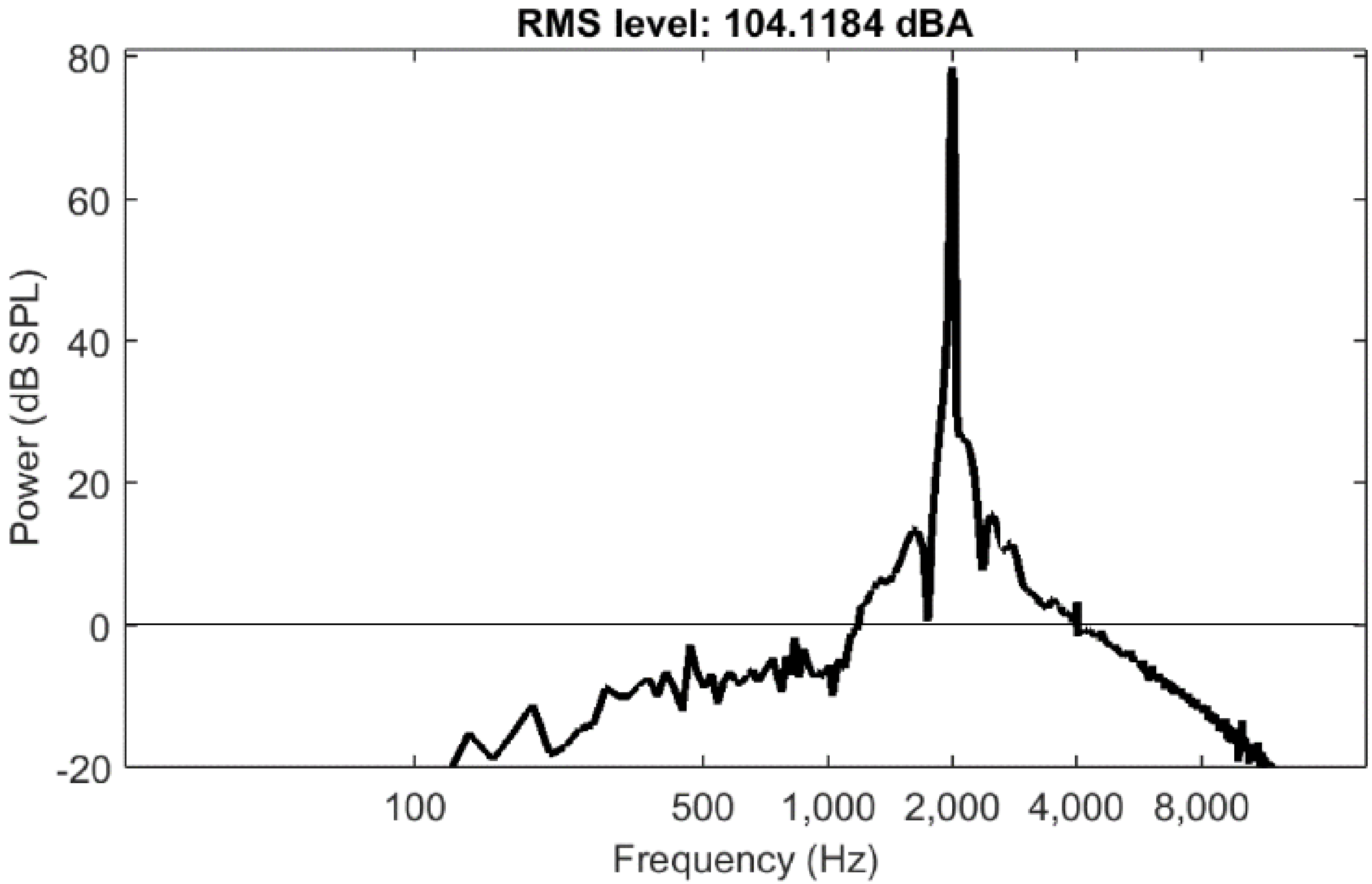


Portable Automated Rapid Testing (PART)

https://bgc.ucr.edu/games

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





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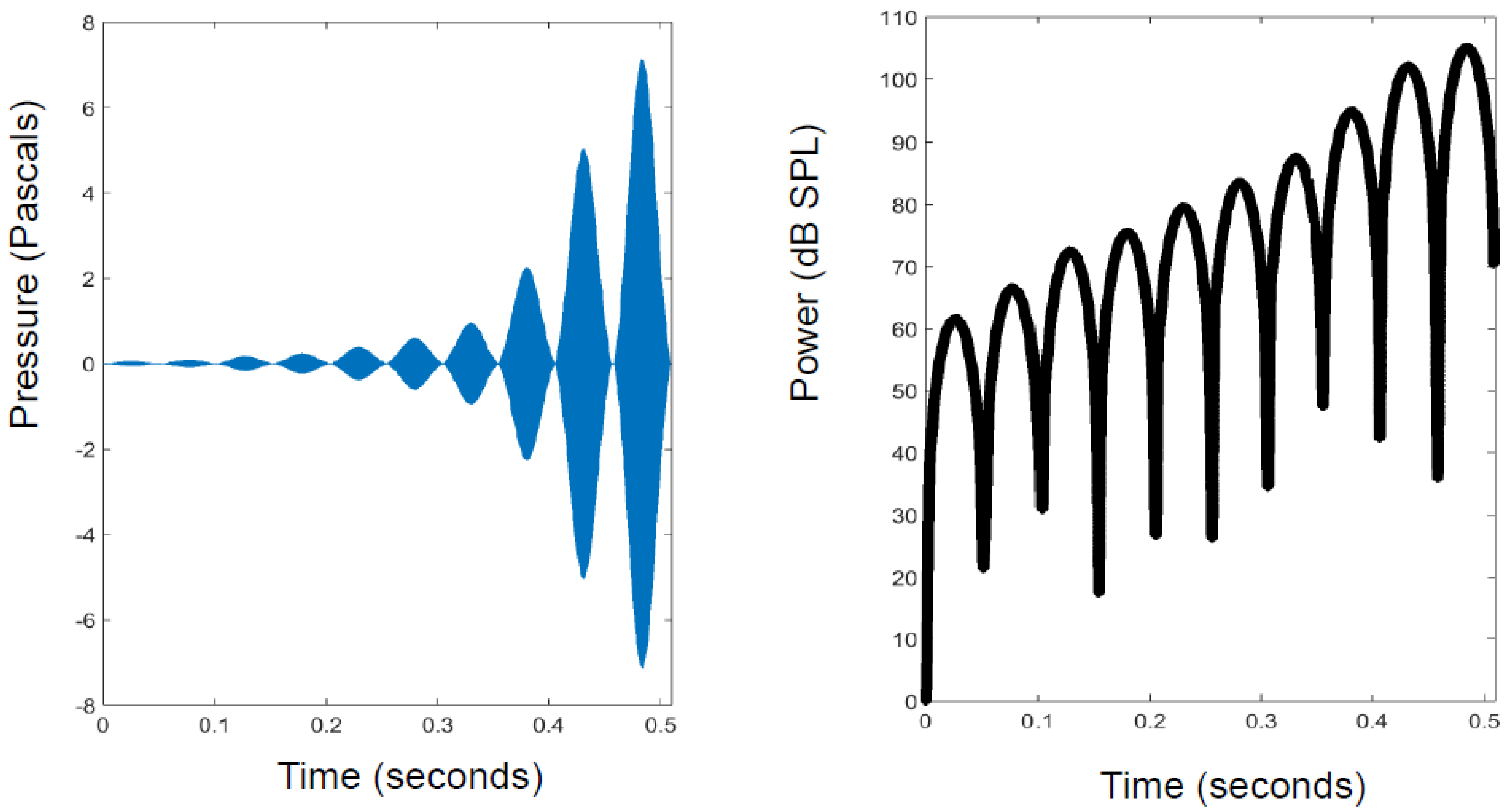
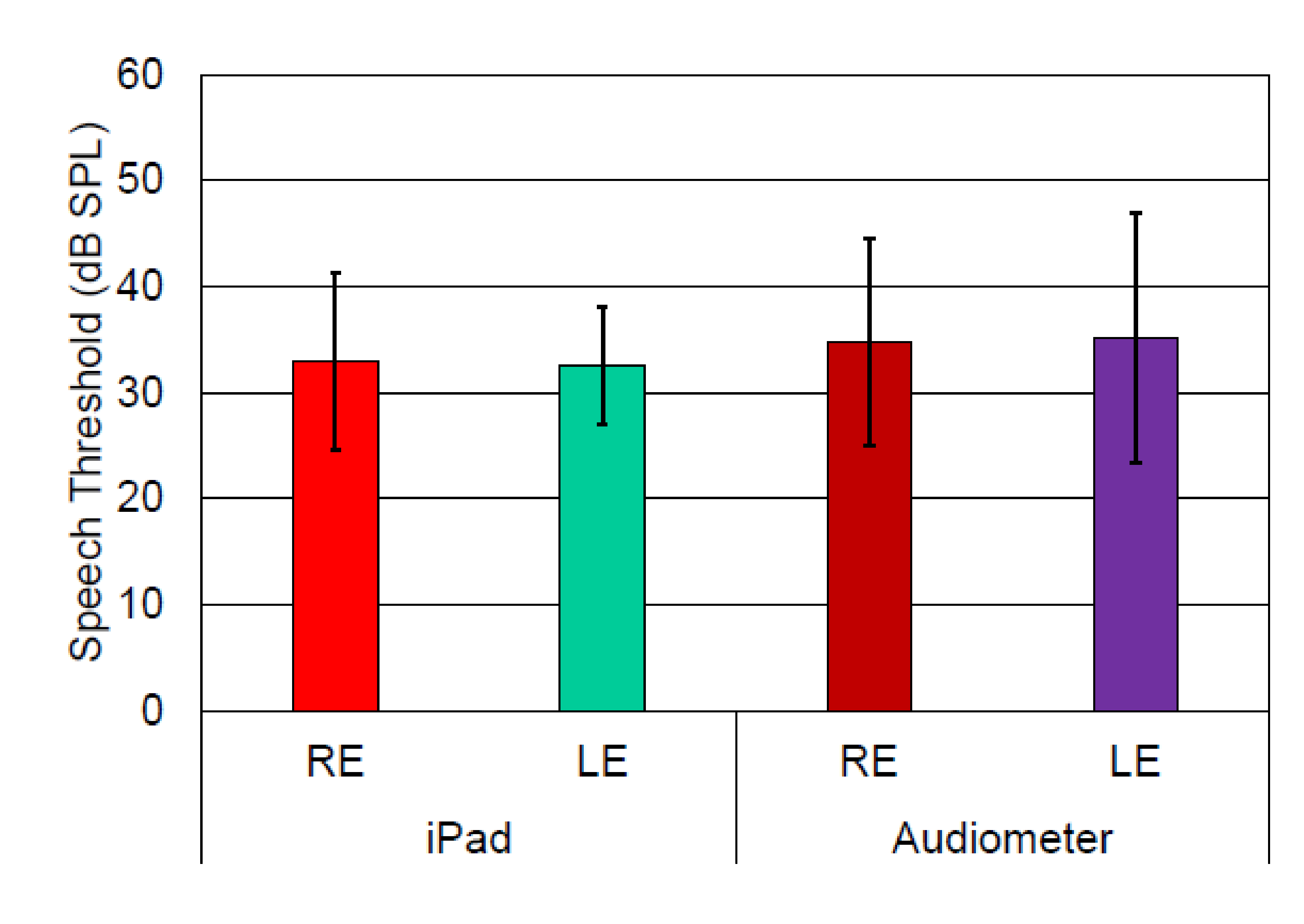


Ten Pulses Varying between 60 and 105 dB SPL (peak-to-peak equivalent)



Behavioral verification involved comparison of intelligibility of speech through the iPad system and a calibrated audiometer.

iPad thresholds were as good or better than the thresholds obtained with speech audiometry

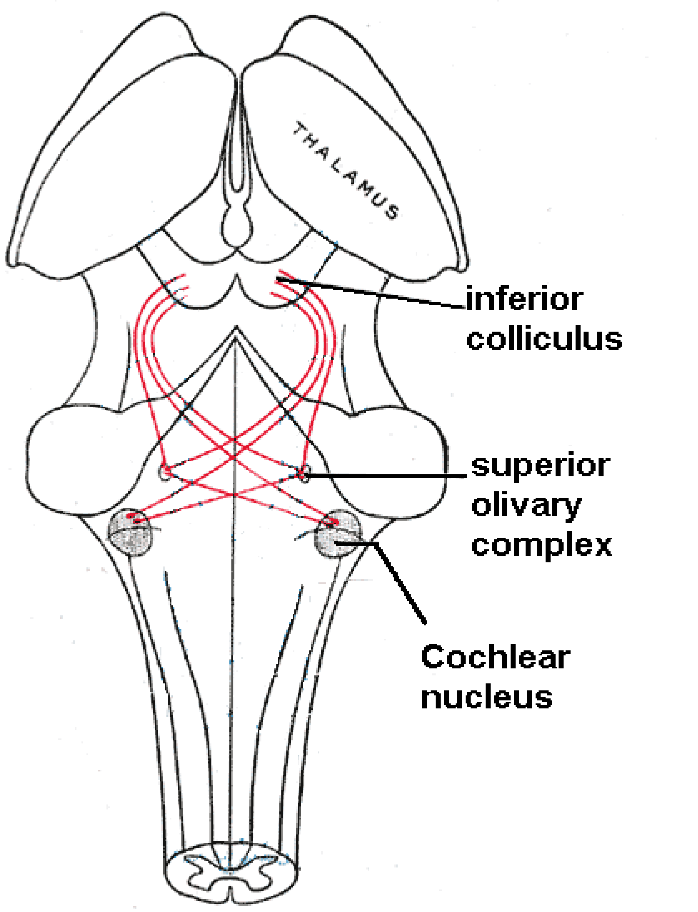
The auditory processing tests included in PART are based on how modern neuroscience describes the functions of the central auditory system.

PART 3

Auditory Neuroscience

Current understanding of the functions of the central auditory system

Functions of the Central Auditory System



Thalamus:

Organization and updating of cortical-brainstem connections

Inferior Colliculus:

Coding of basic timing and frequency patterns

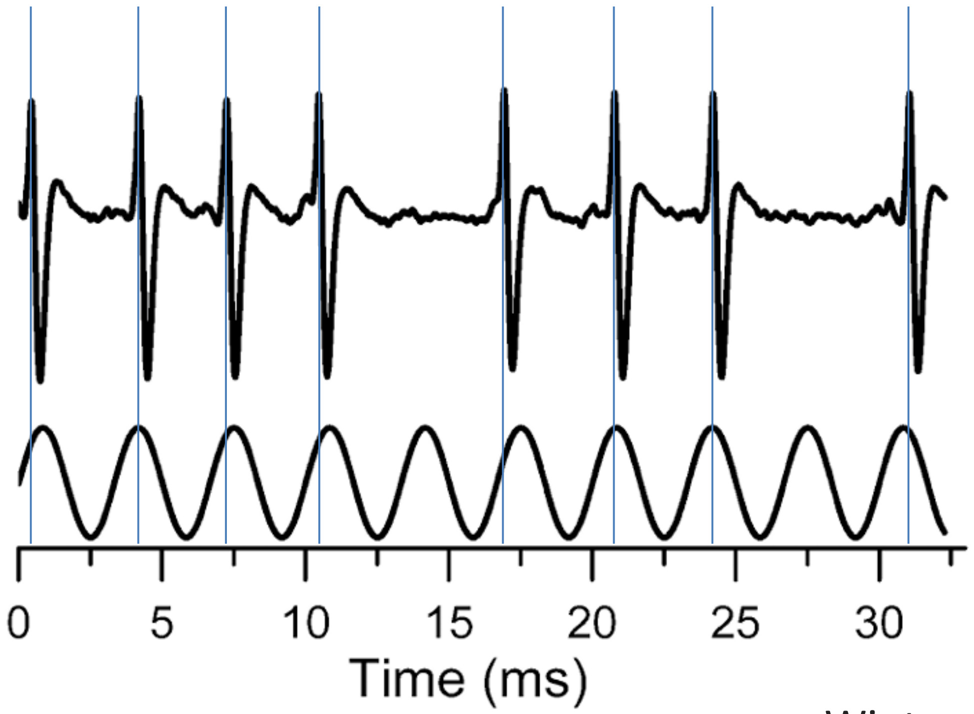
Superior Olivary Complex:

Spatial Processing

Cochlear Nucleus:

Timing and frequency coding

Cochlear Nucleus: Timing and frequency coding



RESPONSE of a cochlear nucleus neuron

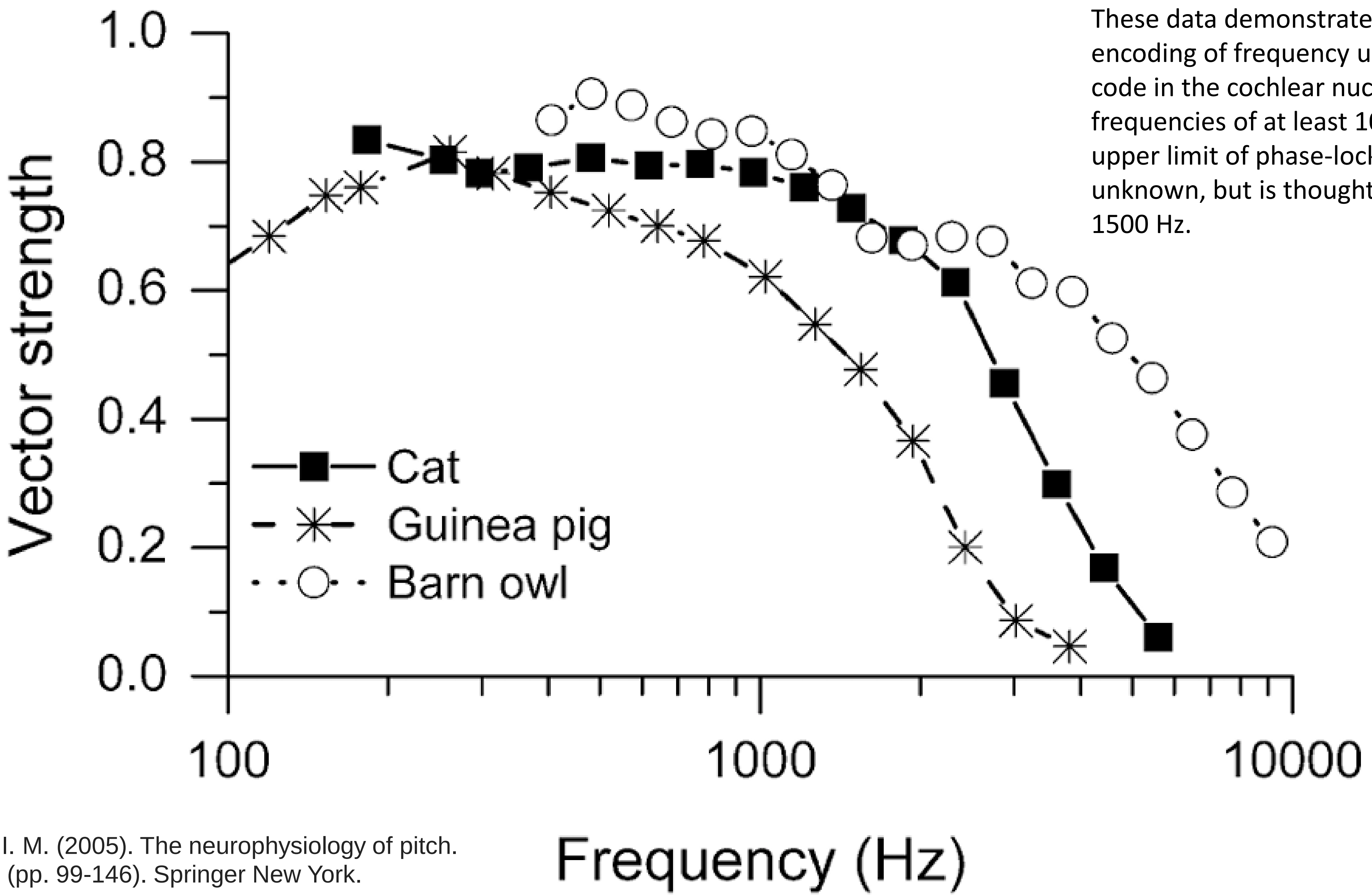
STIMULUS: 300 Hz Tone

Winter, I. M. (2005). The neurophysiology of pitch. In *Pitch* (pp. 99-146). Springer New York.

“Vector Strength” or “Periodicity Strength (PS)”: Metric of the “phase-locking” of a neural response to the periodicity of a stimulus (varies between 0 and 1)

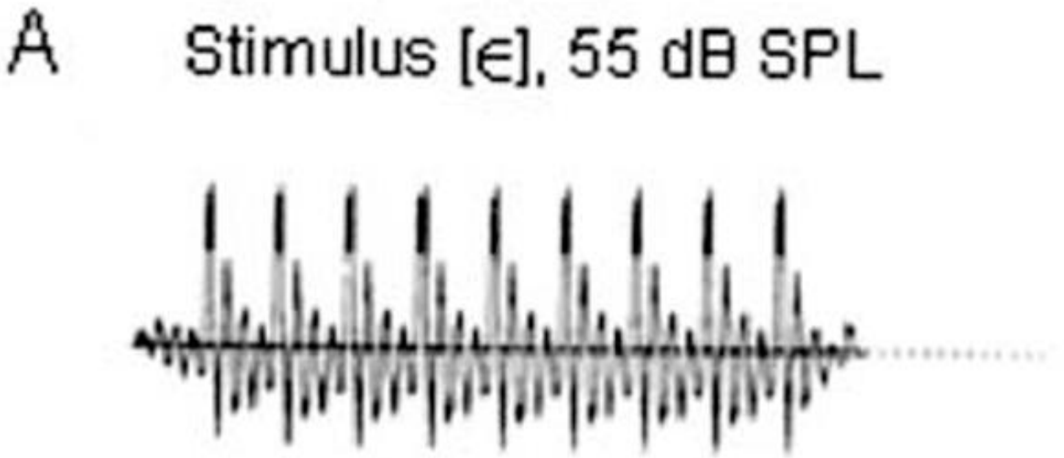
0: Neural spikes can occur at any time
1: Neural spikes only occur during one phase of the stimulus

Vector Strengths of Cochlear Nucleus neurons as a function of frequency and species



These data demonstrate the strong encoding of frequency using a timing code in the cochlear nucleus, up to frequencies of at least 1000 Hz. The upper limit of phase-locking in humans is unknown, but is thought to be about 1500 Hz.

Winter, I. M. (2005). The neurophysiology of pitch. In *Pitch* (pp. 99-146). Springer New York.



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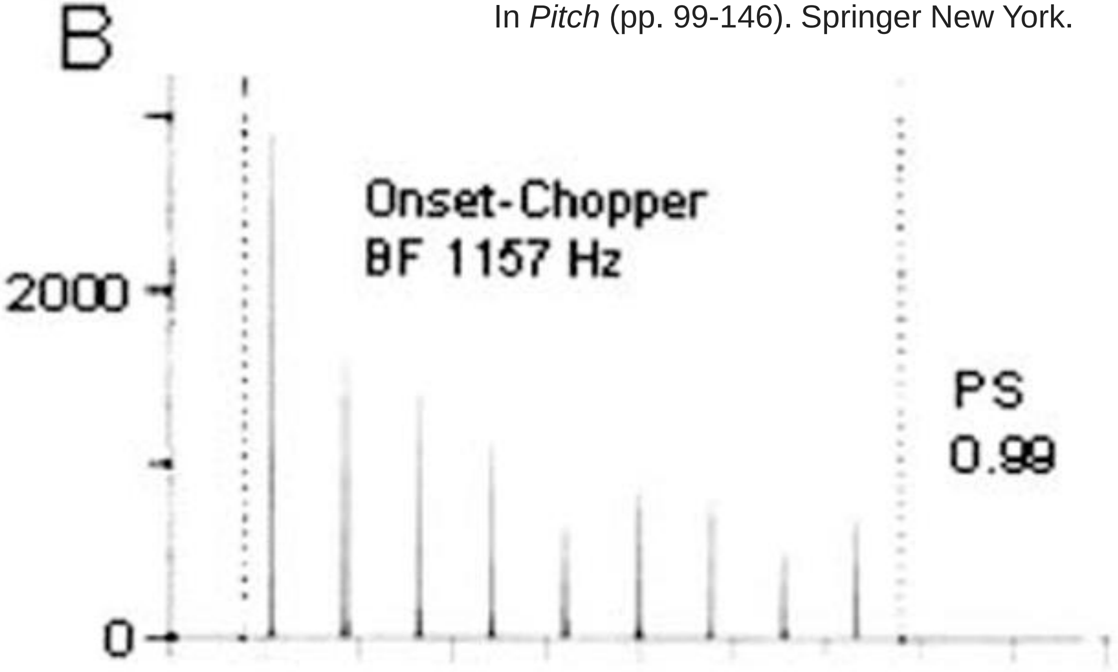
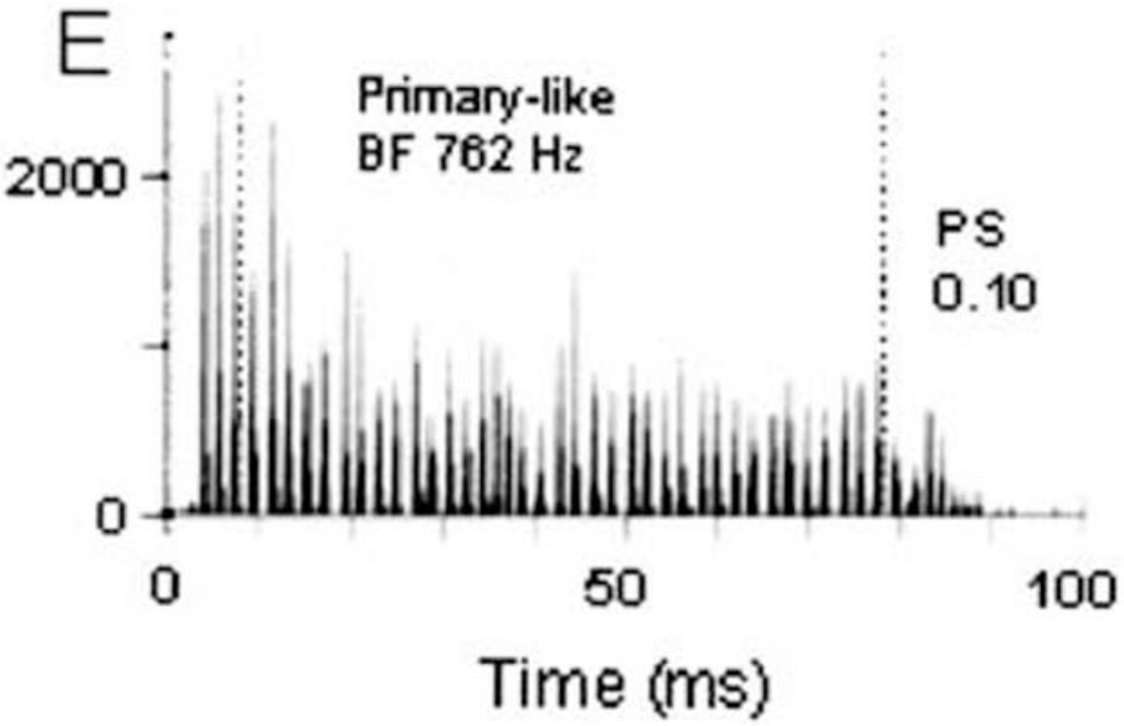


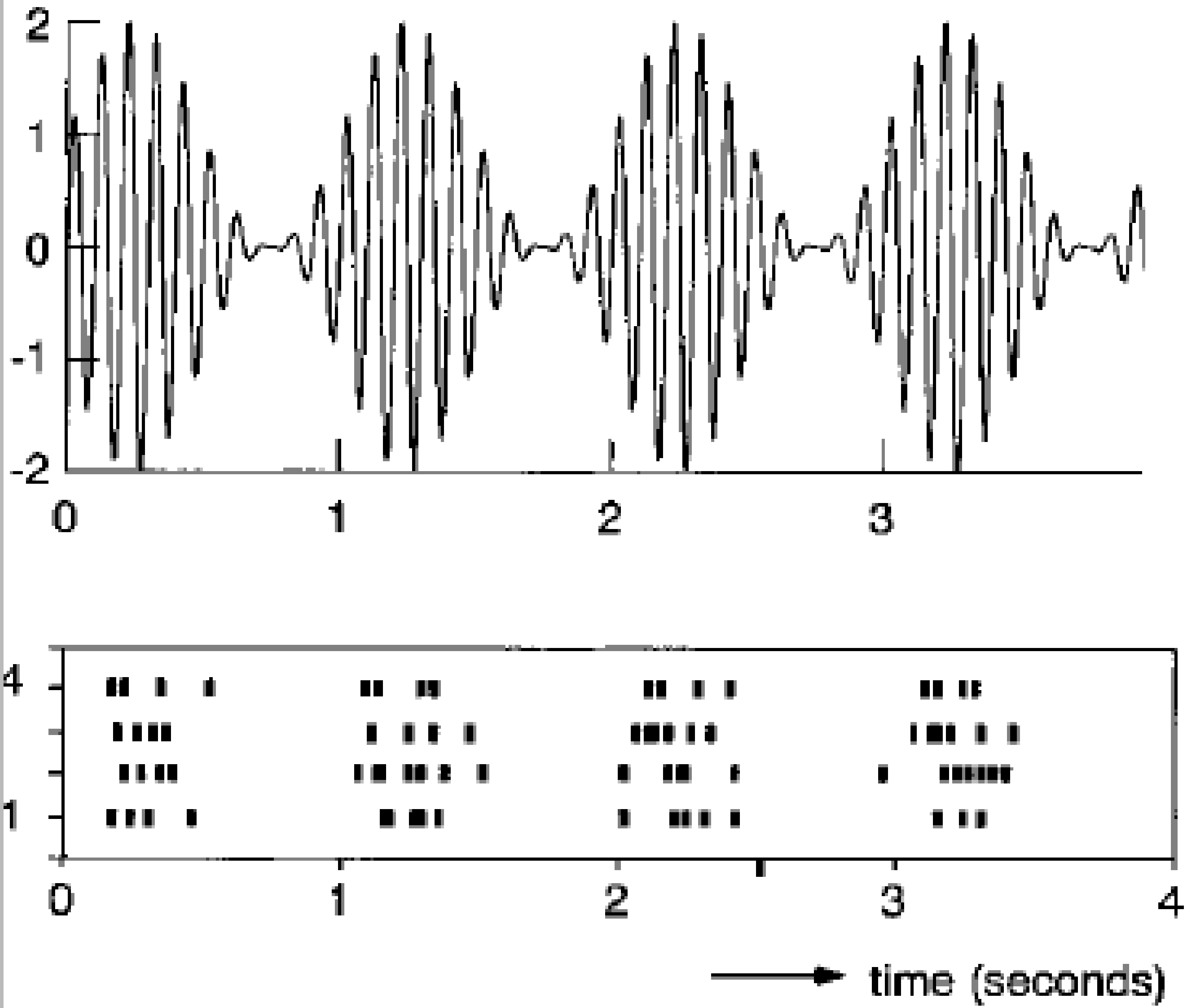


The firing patterns in different cochlear nucleus units

Periodicity Strength (PS) is best for the onset-chopper

The Primary-like units are so named because their responses resemble the responses of the auditory nerve.

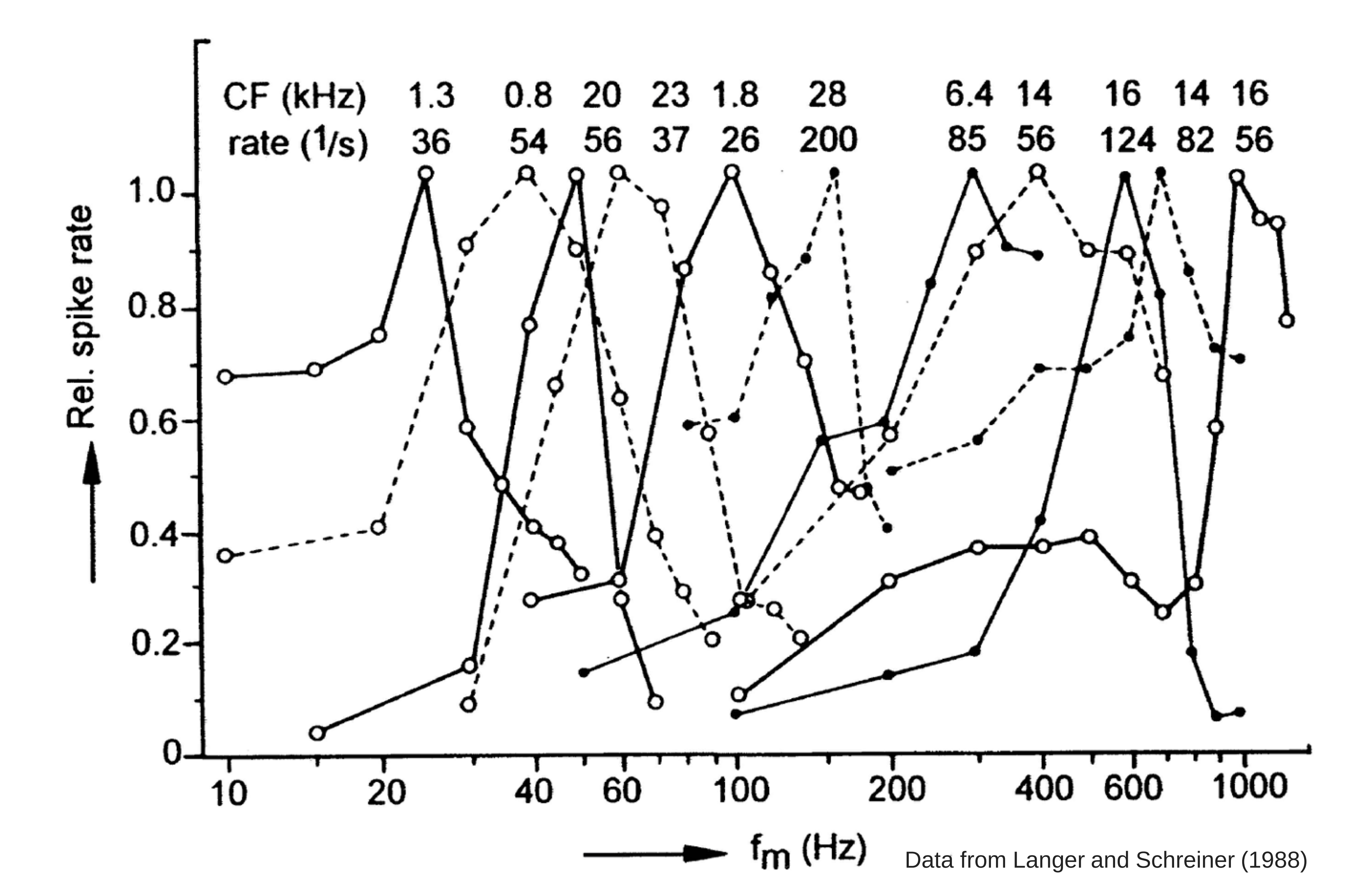
Inferior Colliculus:
Sensitivity to Amplitude Modulation



STIMULUS: 10 Hz Modulation applied to a tone with a higher carrier frequency

RESPONSE of inferior colliculus neurons (each dot represents a spike, each row represents a neuron)

Krishna, B. S.,&Semple, M. N. (2000). Auditory temporal processing: responses to sinusoidally amplitude-modulated tones in the inferior colliculus. *Journal of neurophysiology*, *84*(1), 255-273.



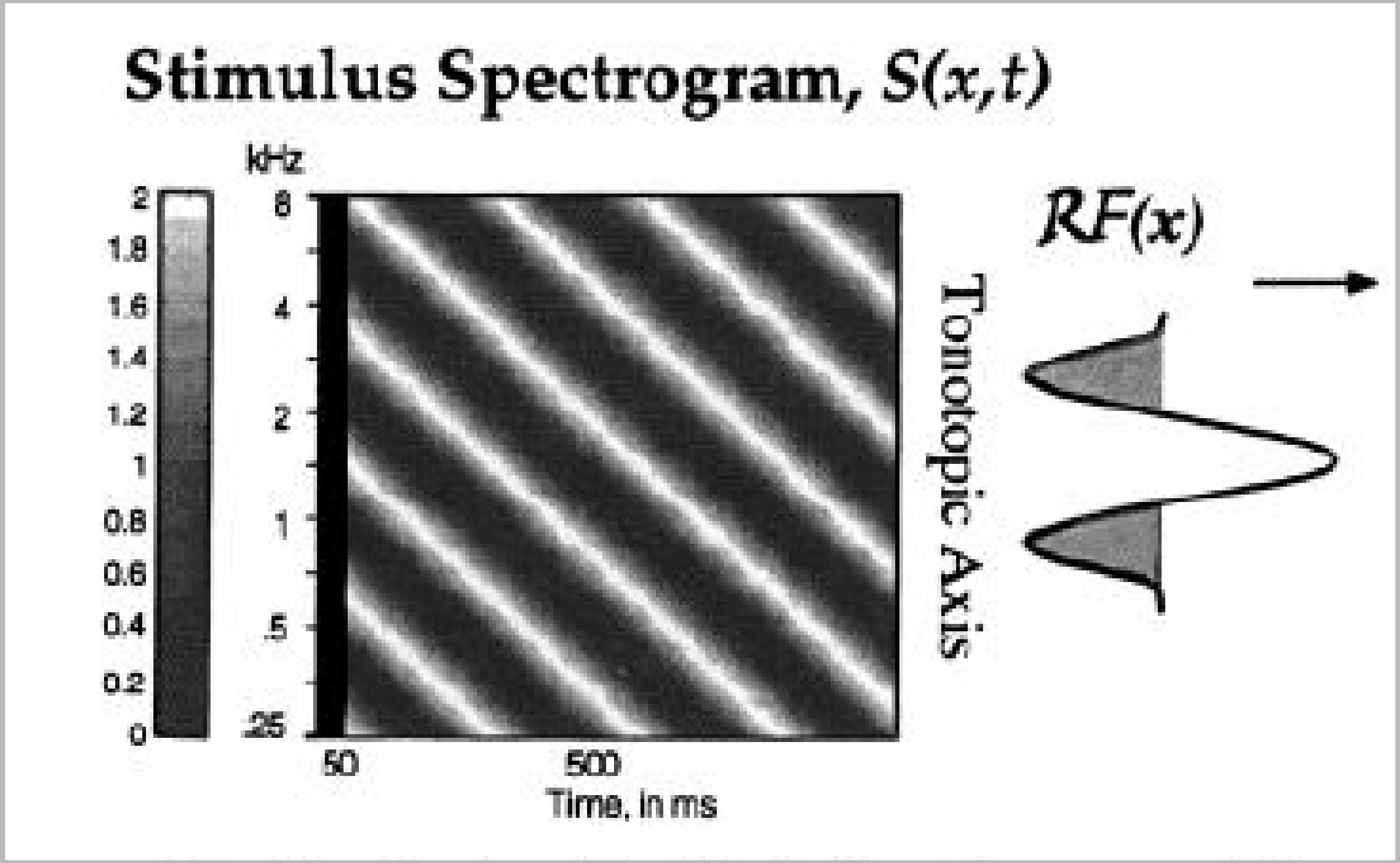
Data from Langer and Schreiner (1988)

Figure from:
Winter, I. M. (2005). The neurophysiology of pitch.
In *Pitch* (pp. 99-146). Springer New York.

Inferior Colliculus: Sensitivity to Amplitude Modulation

Each curve represents a “modulation transfer function” for a different IC neuron

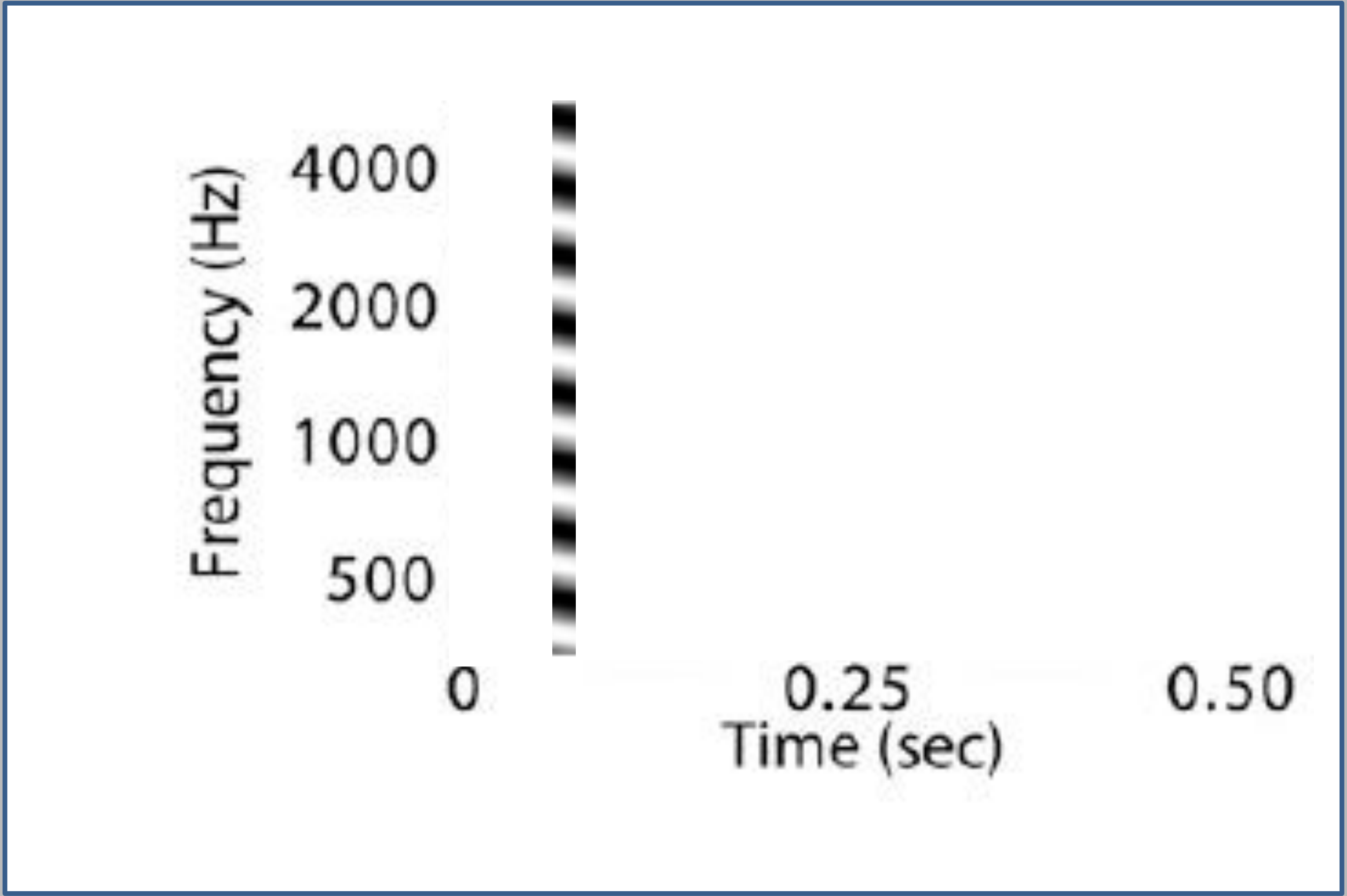
This shows that there is tuning for modulation frequency in IC that is independent of center frequency (CF) or firing rate.



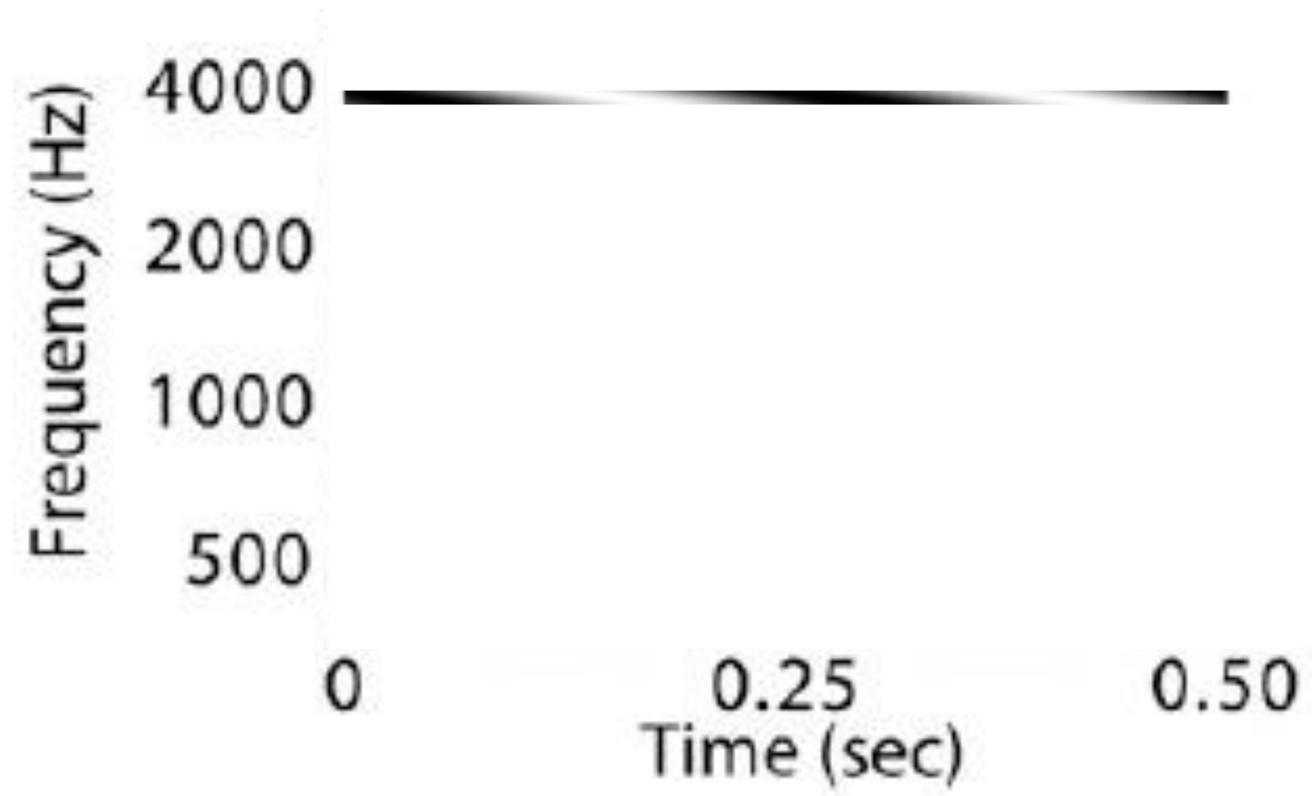
Shamma and his colleagues have argued that spectrotemporal modulation is the unit of analysis at the level of auditory cortex (AC).

AC units are tuned to specific rates of temporal and spectral modulation.

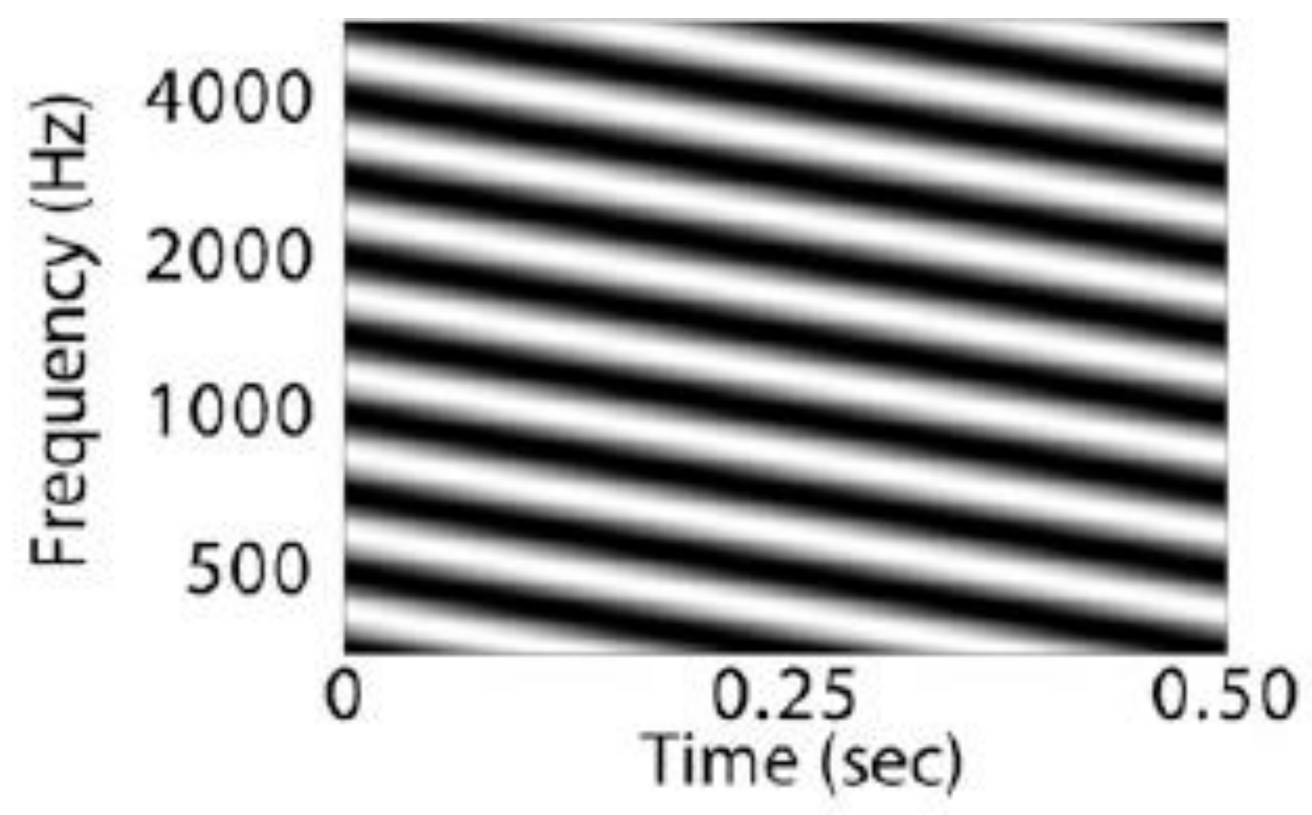
Spectral Modulation in an Auditory Stimulus

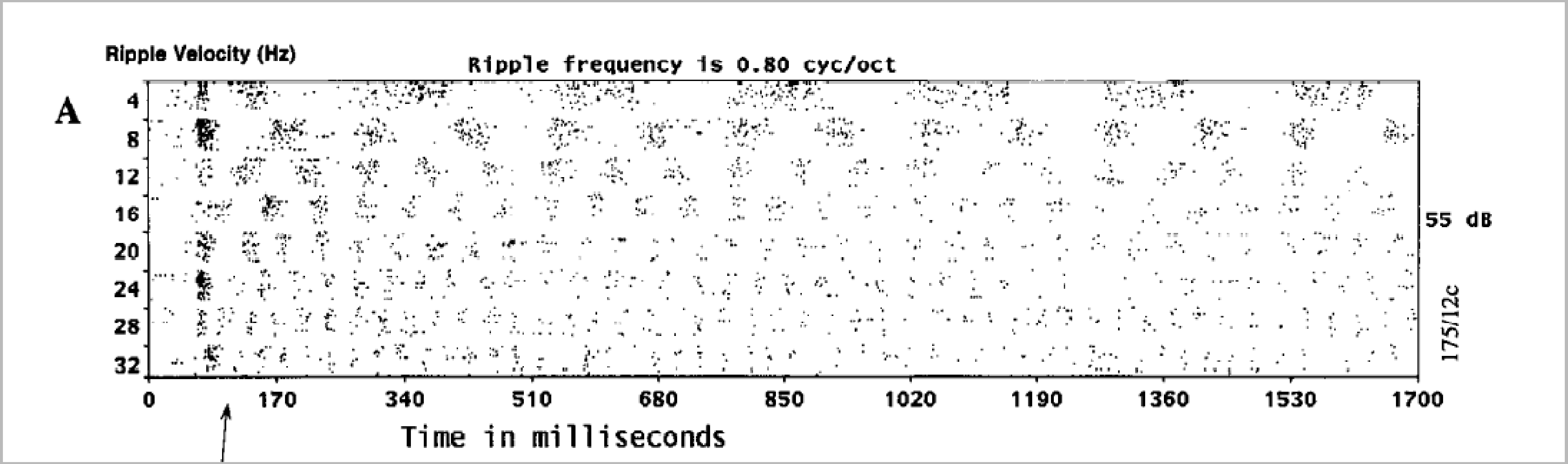


Temporal Modulation in an Auditory Stimulus



Spectral and Temporal Modulation in an Auditory Stimulus



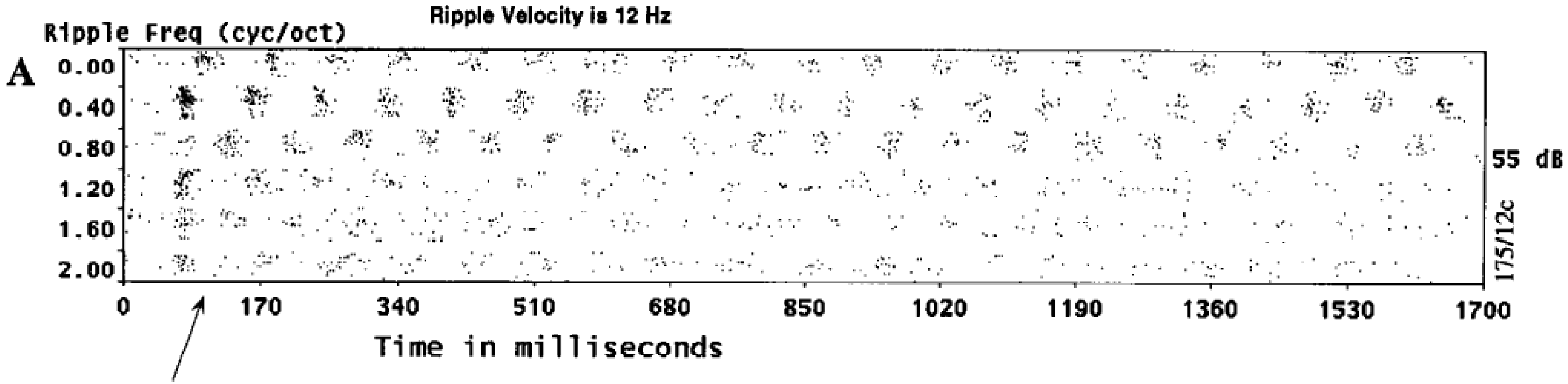


Auditory cortical units are tuned in temporal modulation

JOURNAL OF NEUROPHYSIOLOGY
Vol. 76, No. 5, November 1996. *Printed in U.S.A.*

Analysis of Dynamic Spectra in Ferret Primary Auditory Cortex. I. Characteristics of Single-Unit Responses to Moving Ripple Spectra

NINA KOWALSKI, DIDIER A. DEPIREUX, AND SHIHAB A. SHAMMA
Electrical Engineering Department and Institute for Systems Research, University of Maryland, College Park, Maryland 20742-3311



Auditory cortical units are also tuned in spectral modulation

Journal of Neurophysiology
Vol. 76, No. 5, November 1996. *Printed in U.S.A.*

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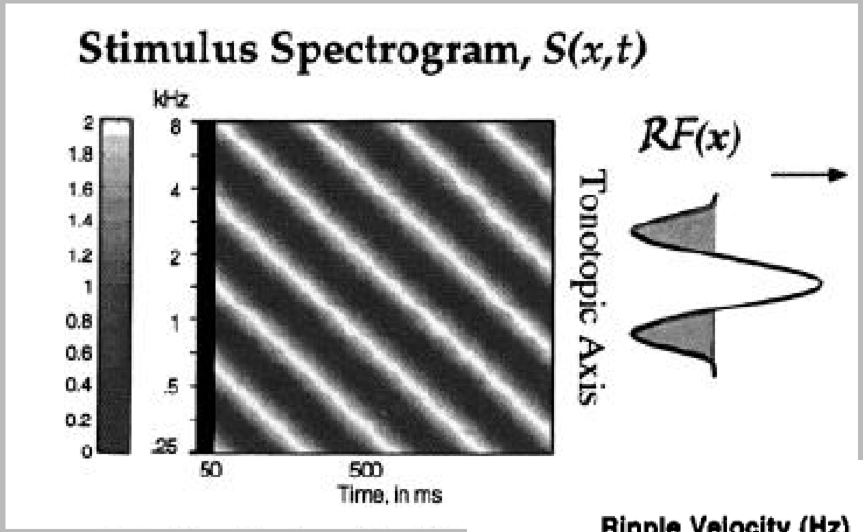

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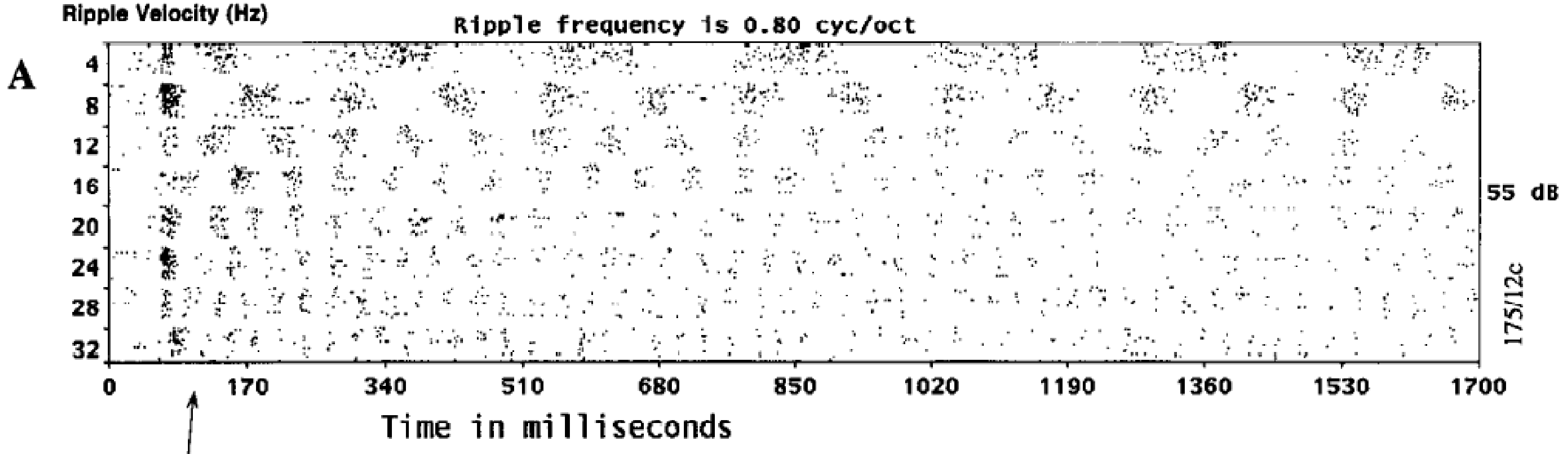

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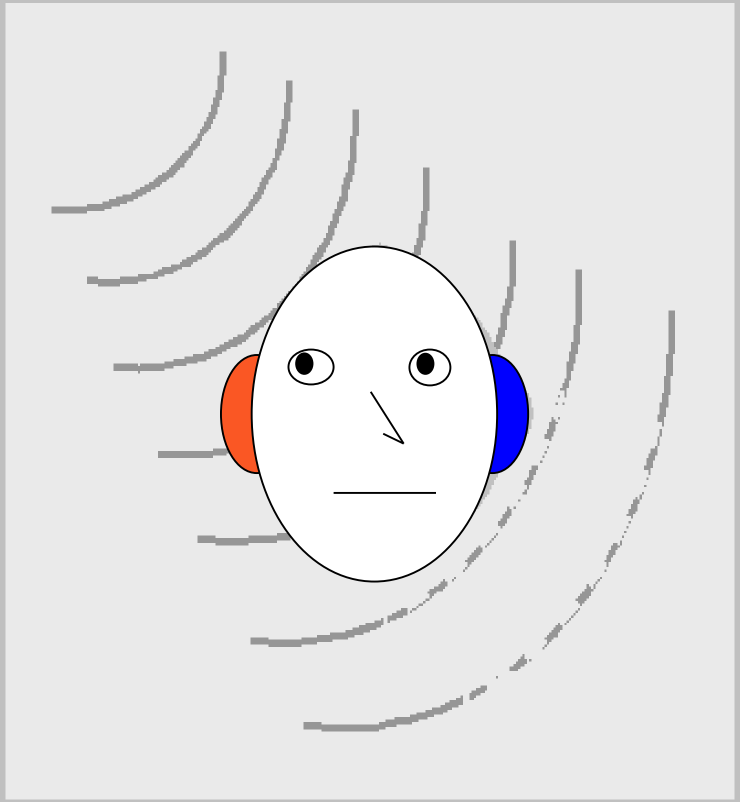
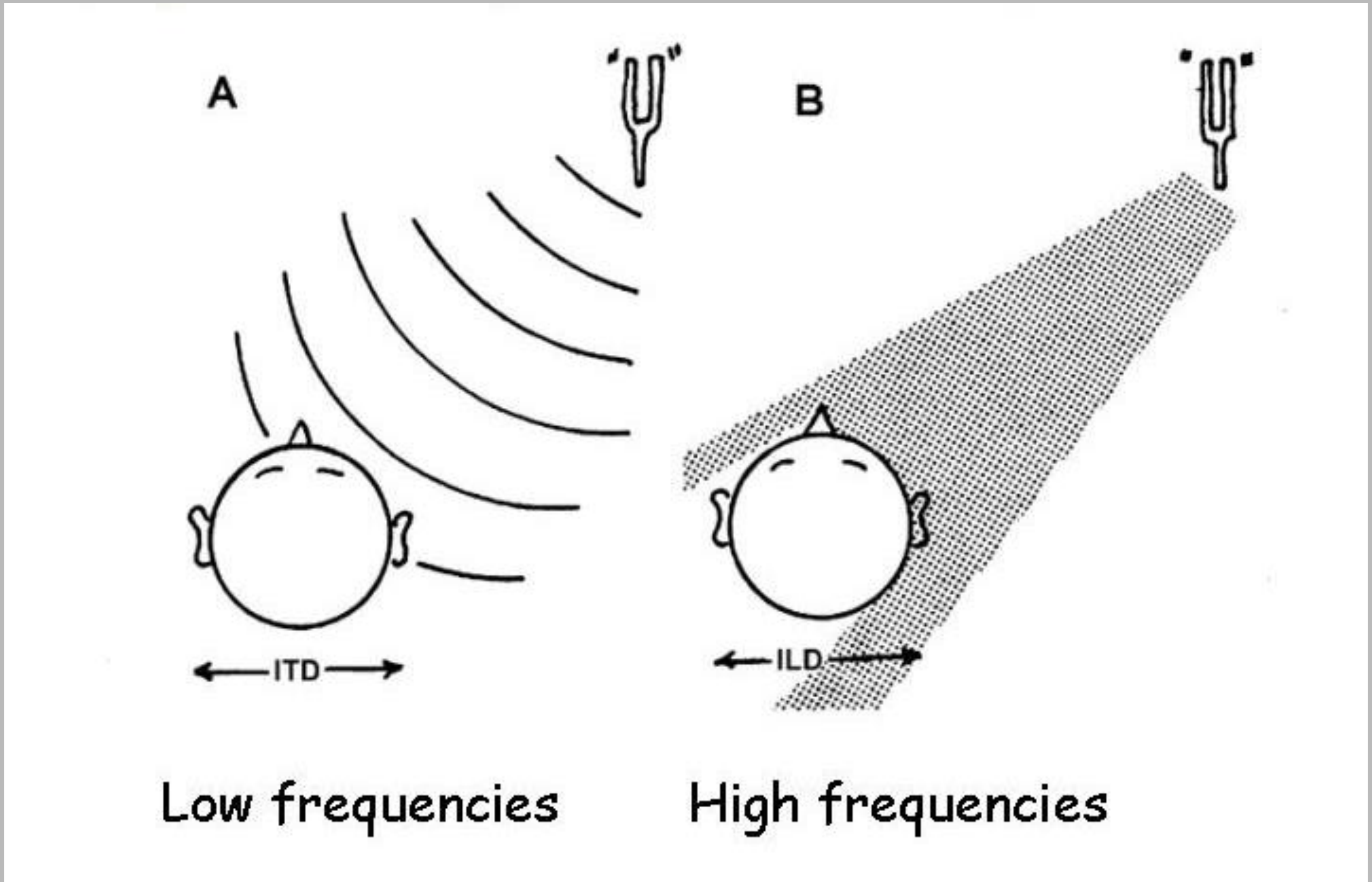
Binaural Hearing

- Having two ears allows spatial location of sounds to be calculated.
- Acoustical differences between the signals are cues listeners can use to determine sound source position in space.
- These acoustical differences can also lead to improved signal detection and identification in complex acoustical environments.

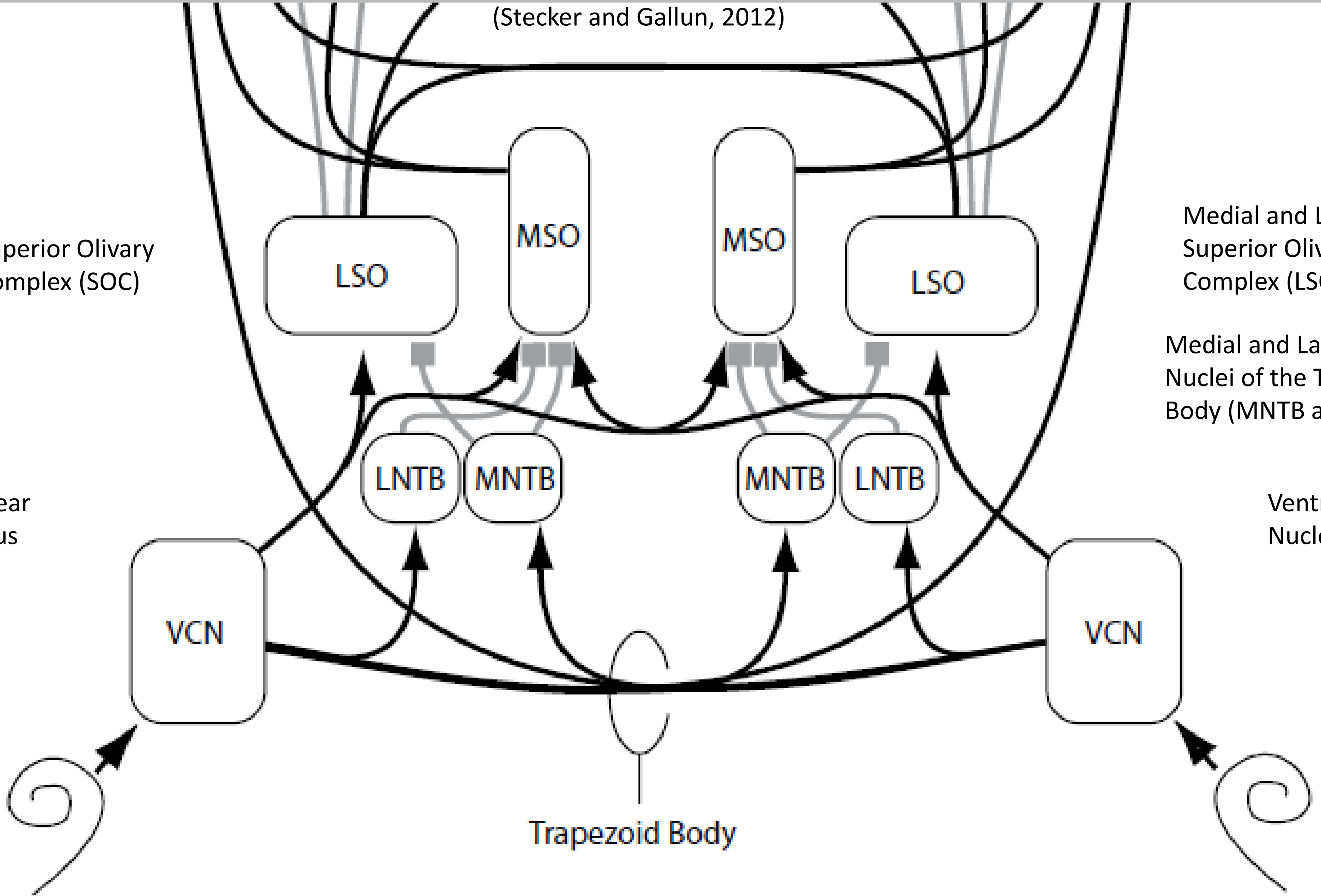


Duplex theory of sound localization (Rayleigh 1907)



Schematic Representation of the Major Binaural Nuclei of the Mammalian Brainstem: Part I

(Stecker and Gallun, 2012)



Superior Olivary Complex (SOC)

Medial and Lateral Superior Olivary Complex (LSO and MSO)

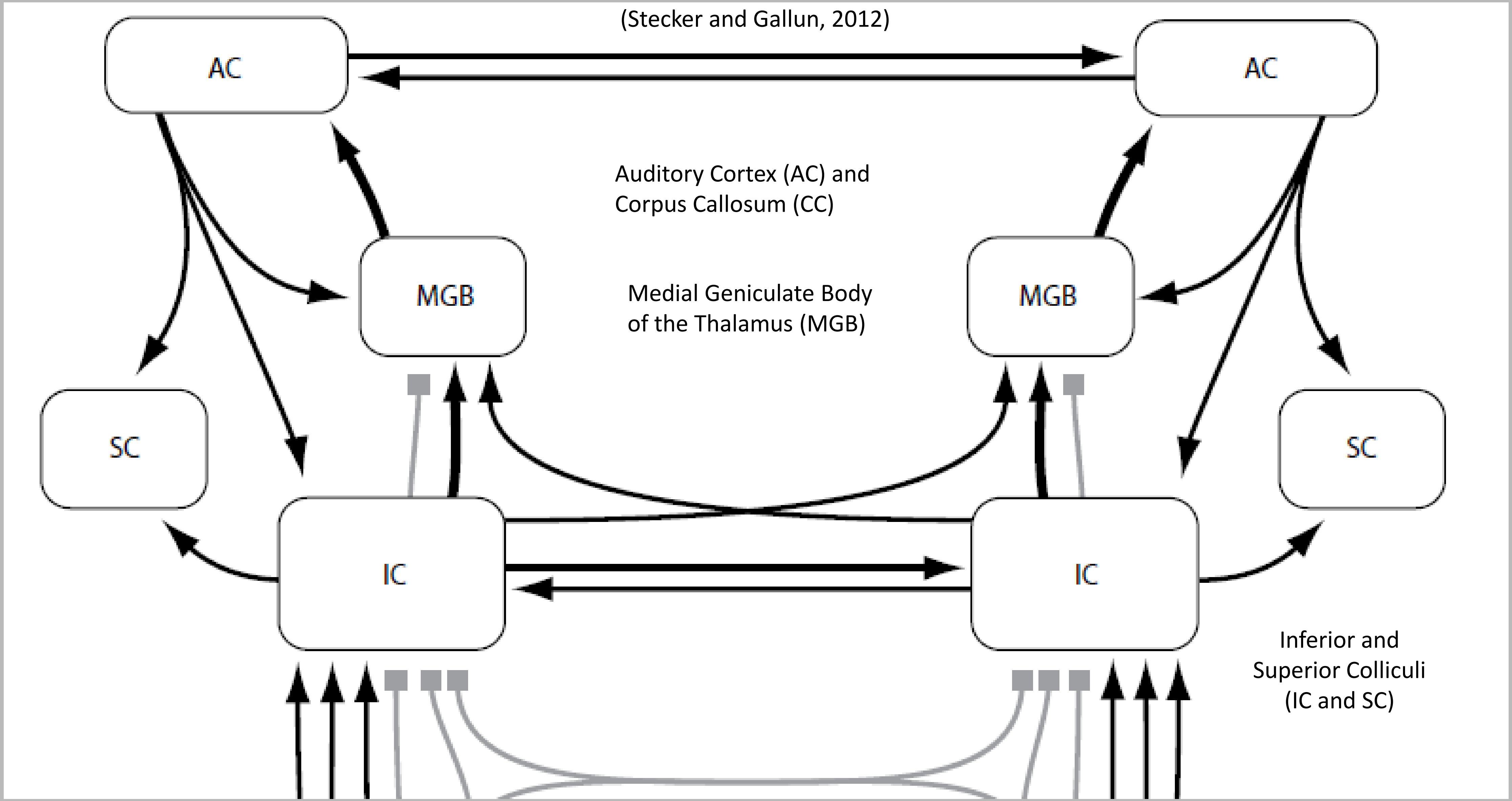
Medial and Lateral Nuclei of the Trapezoidal Body (MNTB and LNTB)

Cochlear nucleus

Ventral Cochlear Nucleus (VCN)

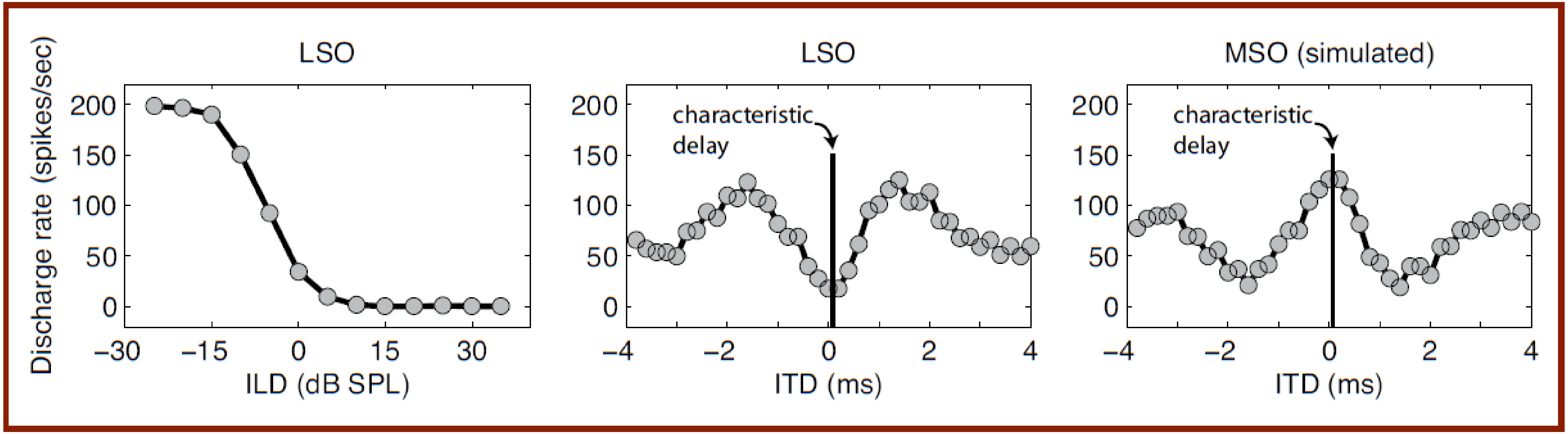
Schematic Representation of the Major Binaural Nuclei of the Mammalian Brainstem: Part II

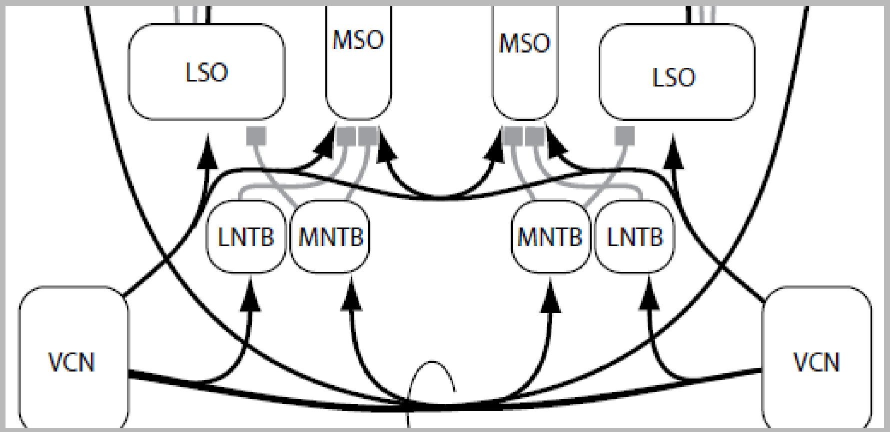
(Stecker and Gallun, 2012)



Firing Patterns of LSO and MSO code Time and Level Differences

(Stecker and Gallun, 2012)





PART 4

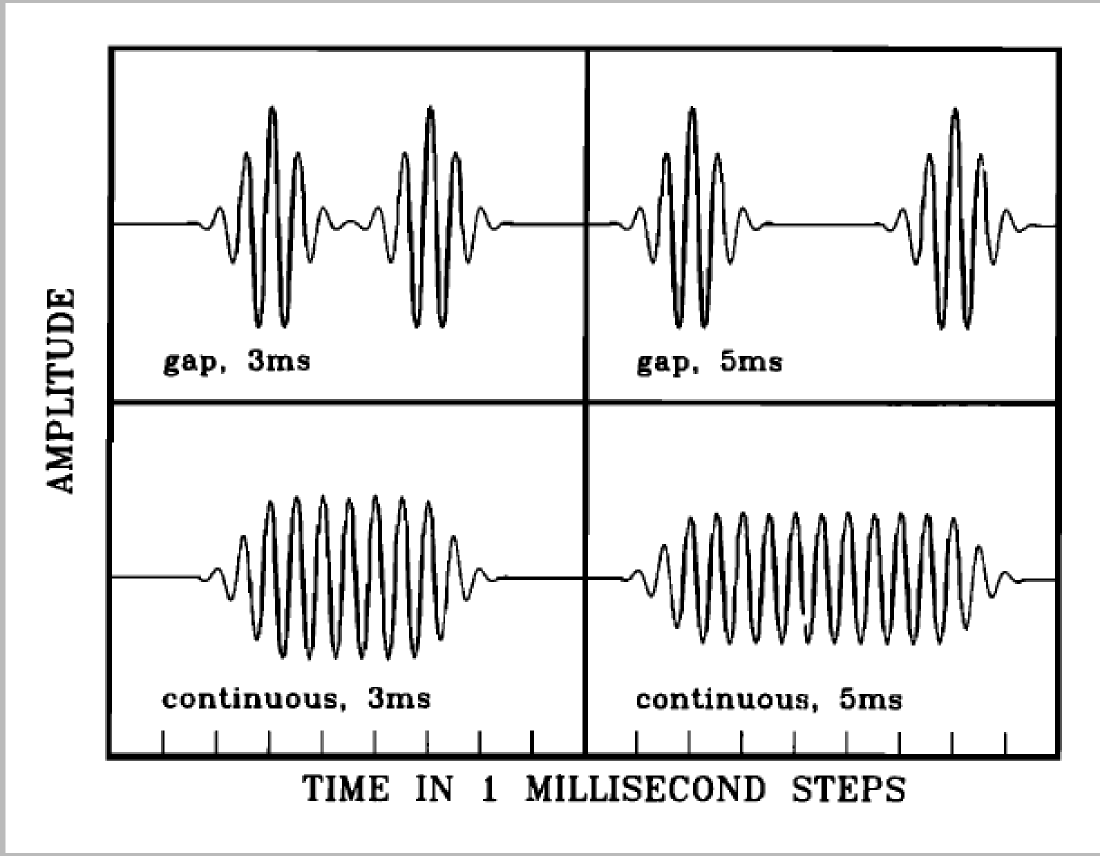
Auditory processing abilities in adults

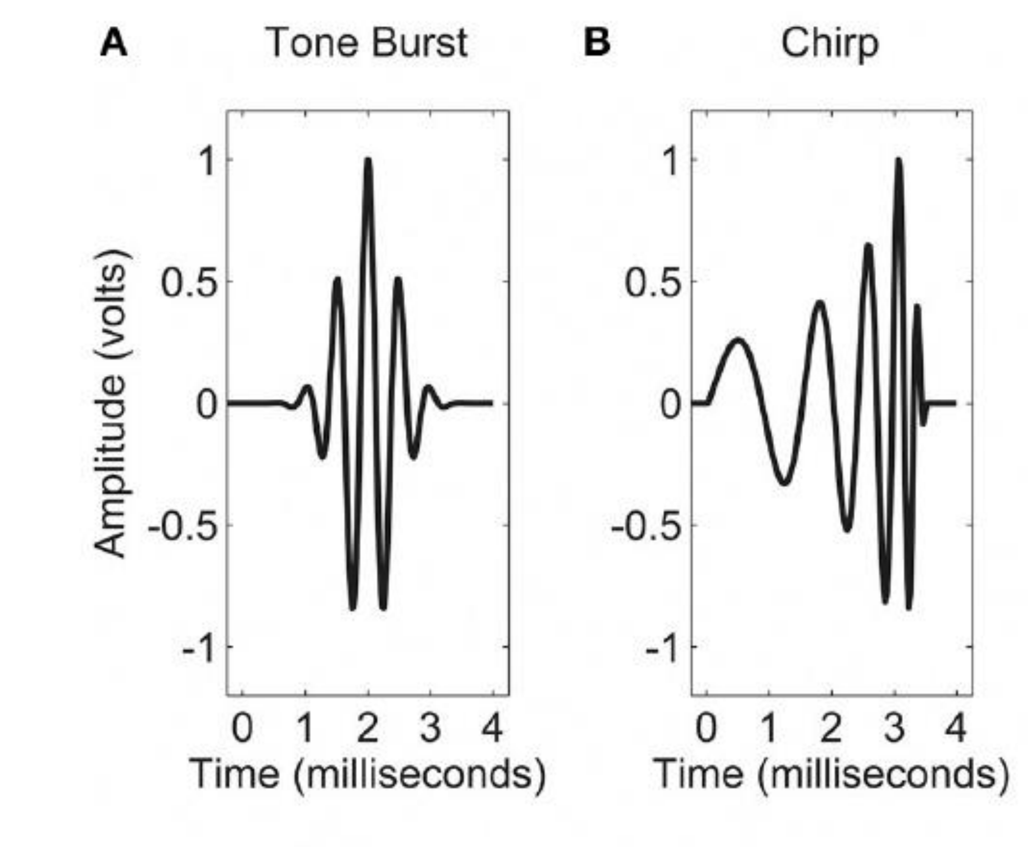
Tests to include in PART

- **Temporal**
- **Spectral**
- **Spectrotemporal**
- **Binaural**

Temporal Processing

Gaps in Short and Long Stimuli





Gap detection and the precedence effect in young and old adults

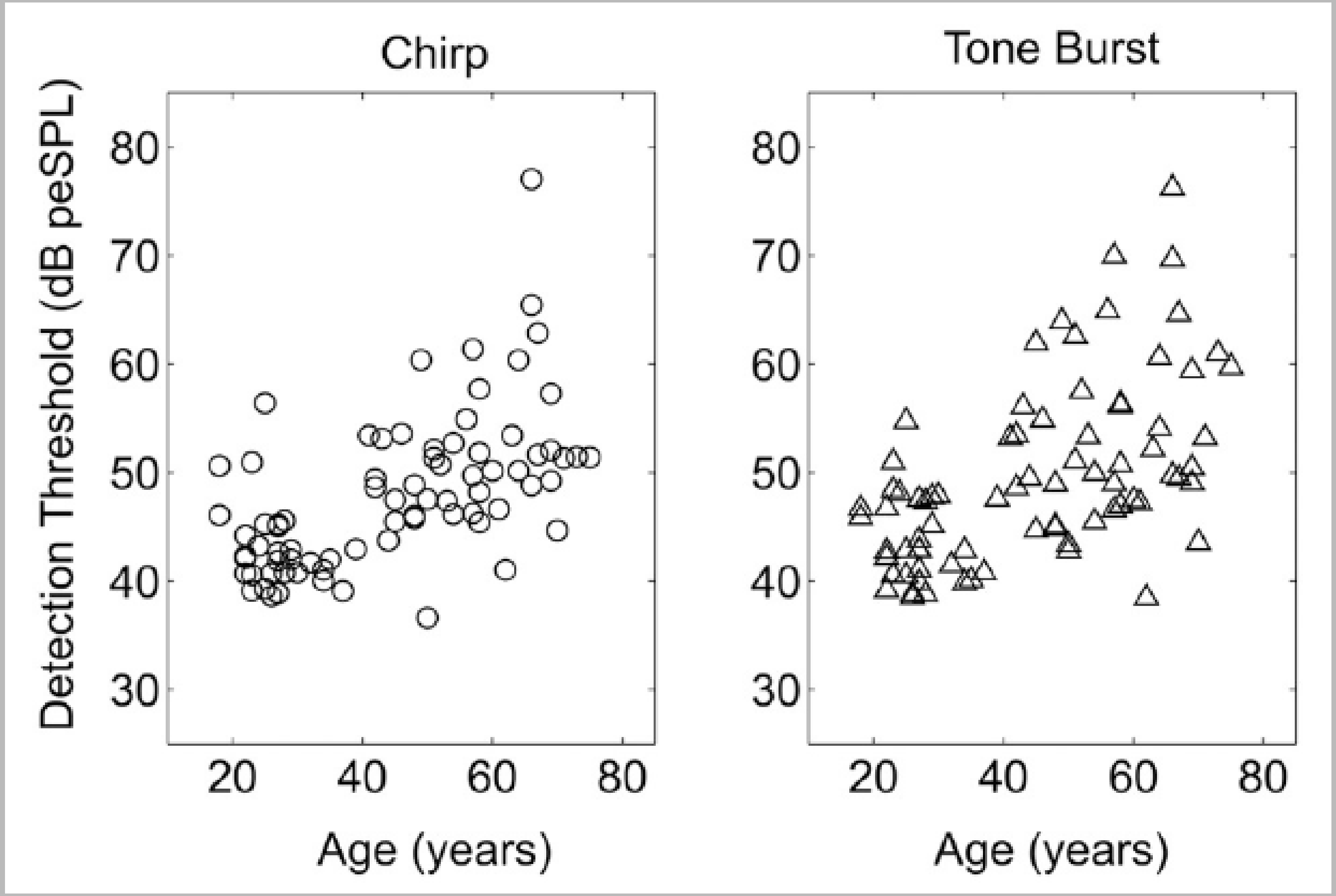
Bruce A. Schneider, Margaret Kathleen Pichora-Fuller,[a] Danielle Kowalchuk, and Morag Lamb
Department of Psychology, University of Toronto, Mississauga, Ontario L5L 1C6, Canada

frontiers in NEUROSCIENCE
ORIGINAL RESEARCH ARTICLE
published: 25 June 2014
doi: 10.3389/fnins.2014.00172

Relating age and hearing loss to monaural, bilateral, and binaural temporal sensitivity[1]

Frederick J. Gallun[1,2], Garnett P. McMillan[1,3], Michelle R. Molis[1,2], Sean D. Kampel[1], Serena M. Dann[1] and Dawn L. Konrad-Martin[1,2]*

[1] National Center for Rehabilitative Auditory Research, Department of Veterans Affairs, Portland VA Medical Center, Portland, OR, USA
[2] Otolaryngology/Head and Neck Surgery, Oregon Health and Science University, Portland, OR, USA
[3] Department of Public Health and Preventive Medicine, Oregon Health and Science University, Portland, OR, USA



Age and detection thresholds were correlated, but tones and chirps had similar detectability, all below 80 dB peSPL

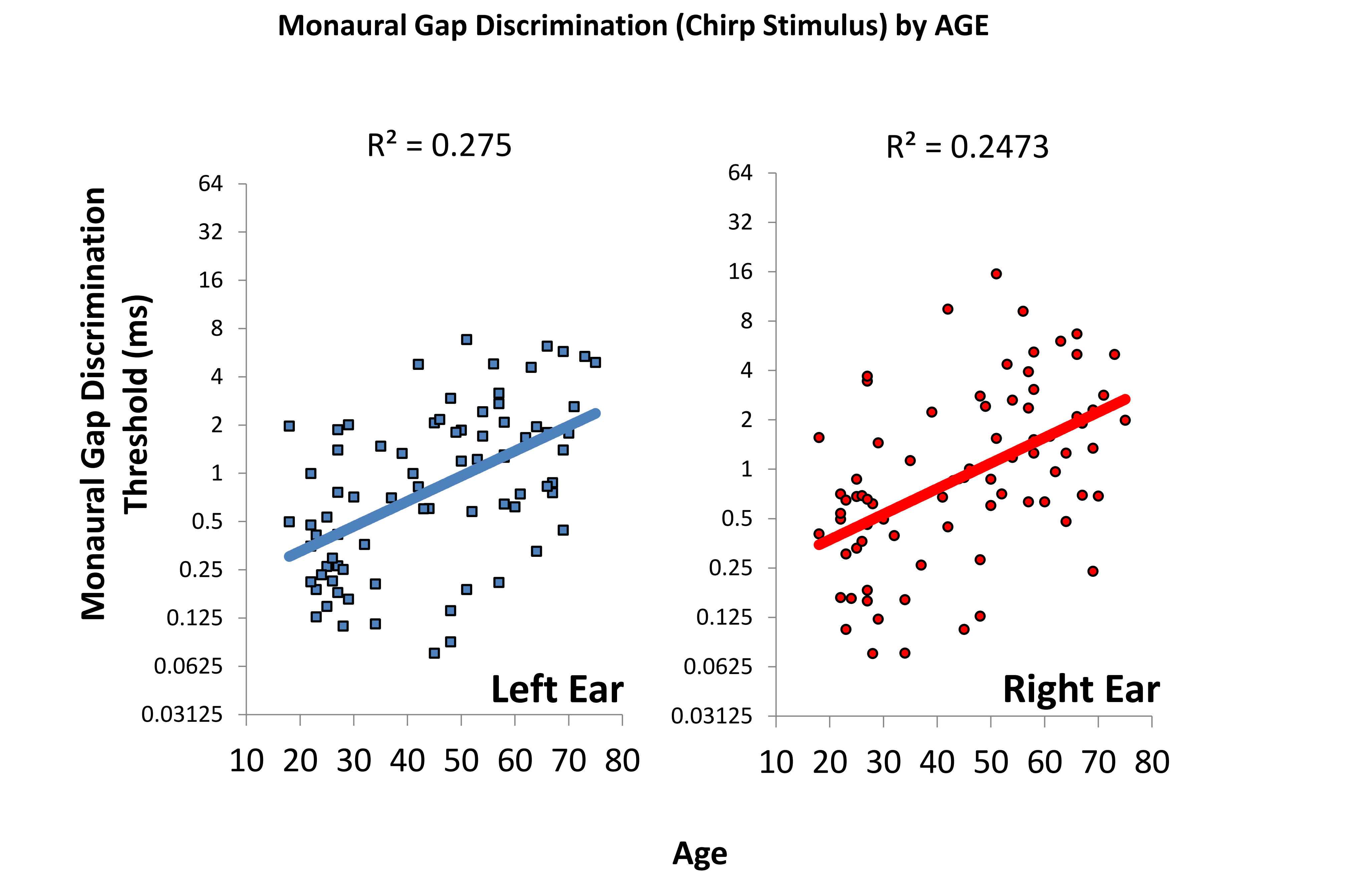
frontiers in NEUROSCIENCE

ORIGINAL RESEARCH ARTICLE
published: 25 June 2014
doi: 10.3389/fnins.2014.00172

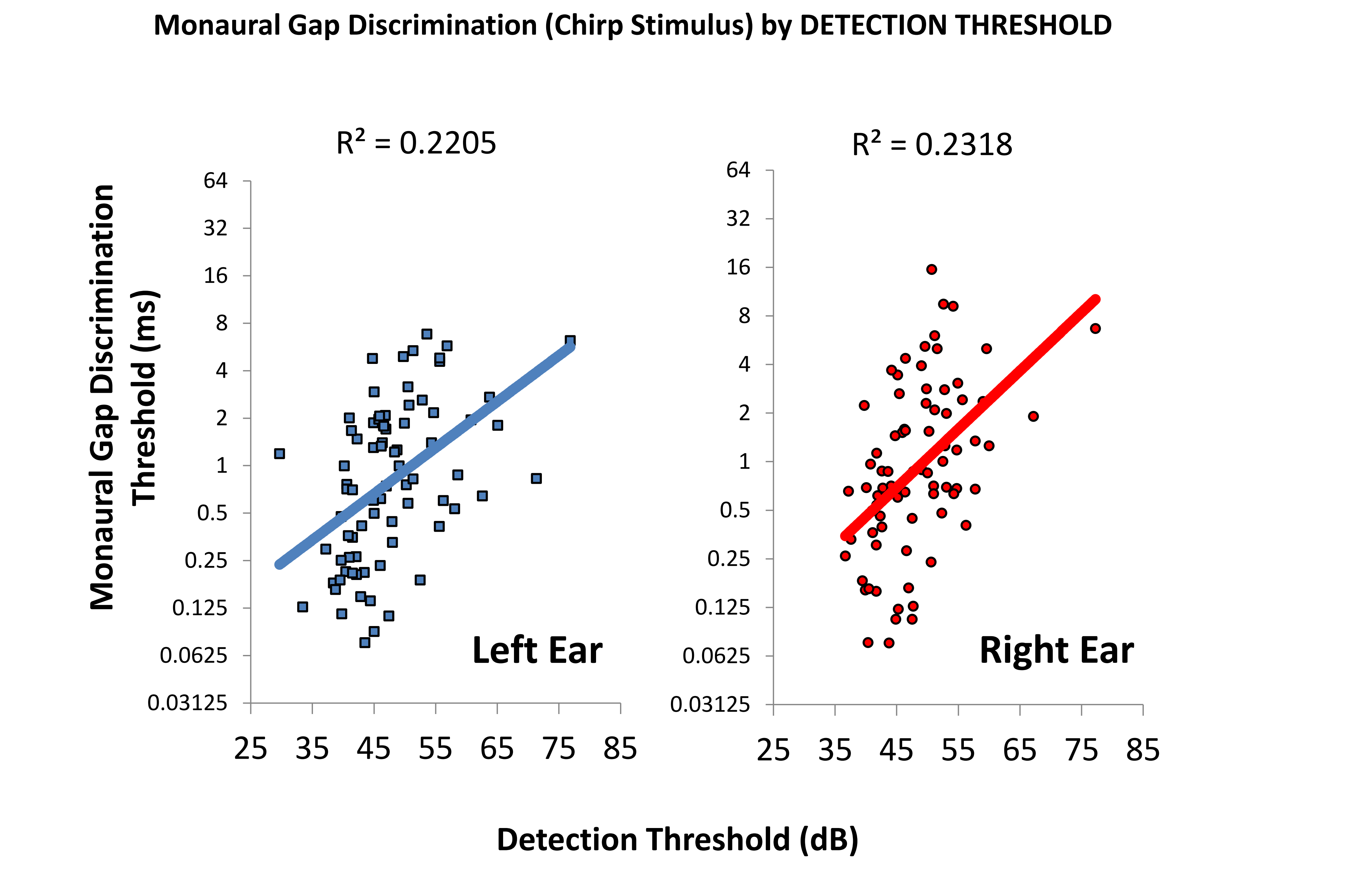
Relating age and hearing loss to monaural, bilateral, and binaural temporal sensitivity[1]

Frederick J. Gallun[1,2]*, Garnett P. McMillan[1,3], Michelle R. Molis[1,2], Sean D. Kampel[1], Serena M. Dann[1] and Dawn L. Konrad-Martin[1,2]

[1] National Center for Rehabilitative Auditory Research, Department of Veterans Affairs, Portland VA Medical Center, Portland, OR, USA
[2] Otolaryngology/Head and Neck Surgery, Oregon Health and Science University, Portland, OR, USA
[3] Department of Public Health and Preventive Medicine, Oregon Health and Science University, Portland, OR, USA

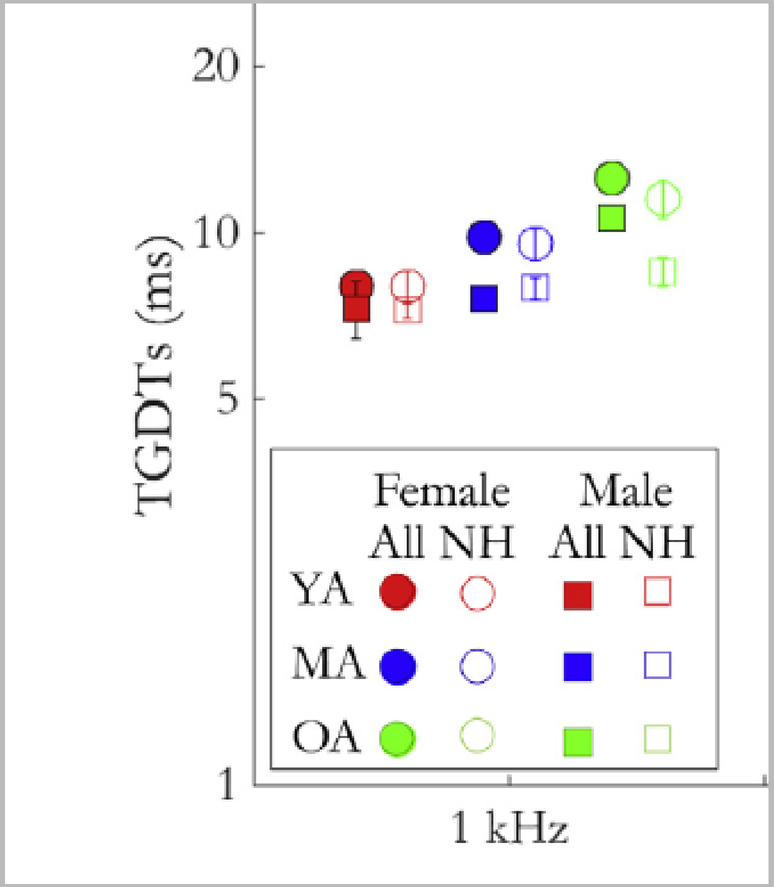


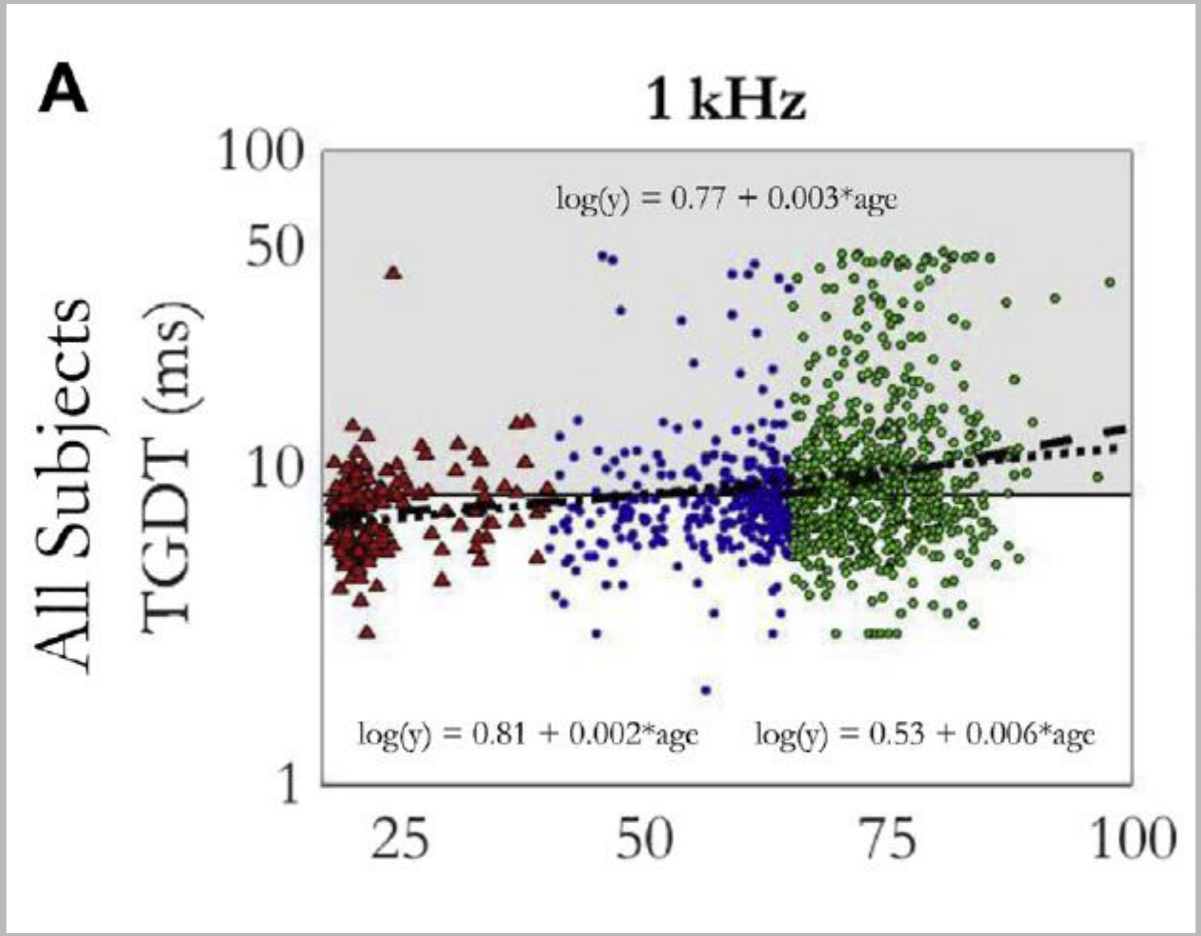
Monaural Gap Discrimination (Chirp Stimulus) by AGE
R² = 0.275
R² = 0.2473
Monaural Gap Discrimination Threshold (ms)
64
32
16
8
4
2
1
0.5
0.25
0.125
0.0625
0.03125
10 20 30 40 50 60 70 80
Left Ear
Right Ear
Age

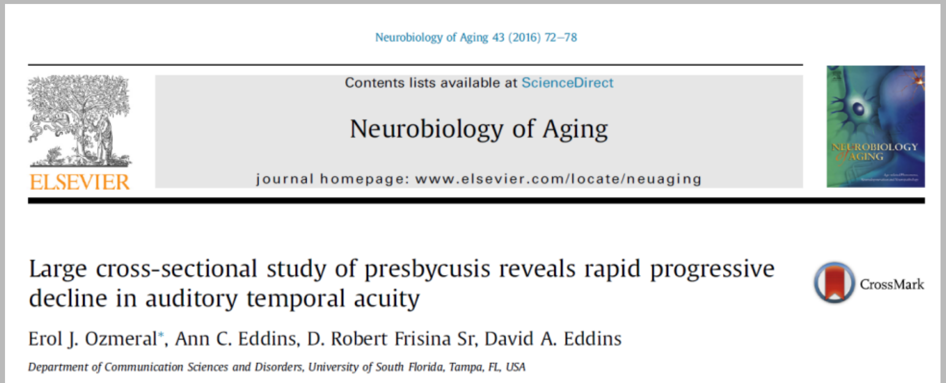


Monaural Gap Discrimination (Chirp Stimulus) by DETECTION THRESHOLD
$R^2 = 0.2205$
$R^2 = 0.2318$
Monaural Gap Discrimination Threshold (ms)
64
32
16
8
4
2
1
0.5
0.25
0.125
0.0625
0.03125
25
35
45
55
65
75
85
Left Ear
Right Ear
Detection Threshold (dB)

Ozmeral et al. (2016) also found effects of age and hearing loss on a gap detection task, using narrowband noises of longer duration.







Neurobiology of Aging 43 (2016) 72–78

Contents lists available at ScienceDirect

Neurobiology of Aging

journal homepage: www.elsevier.com/locate/neuaging

ELSEVIER

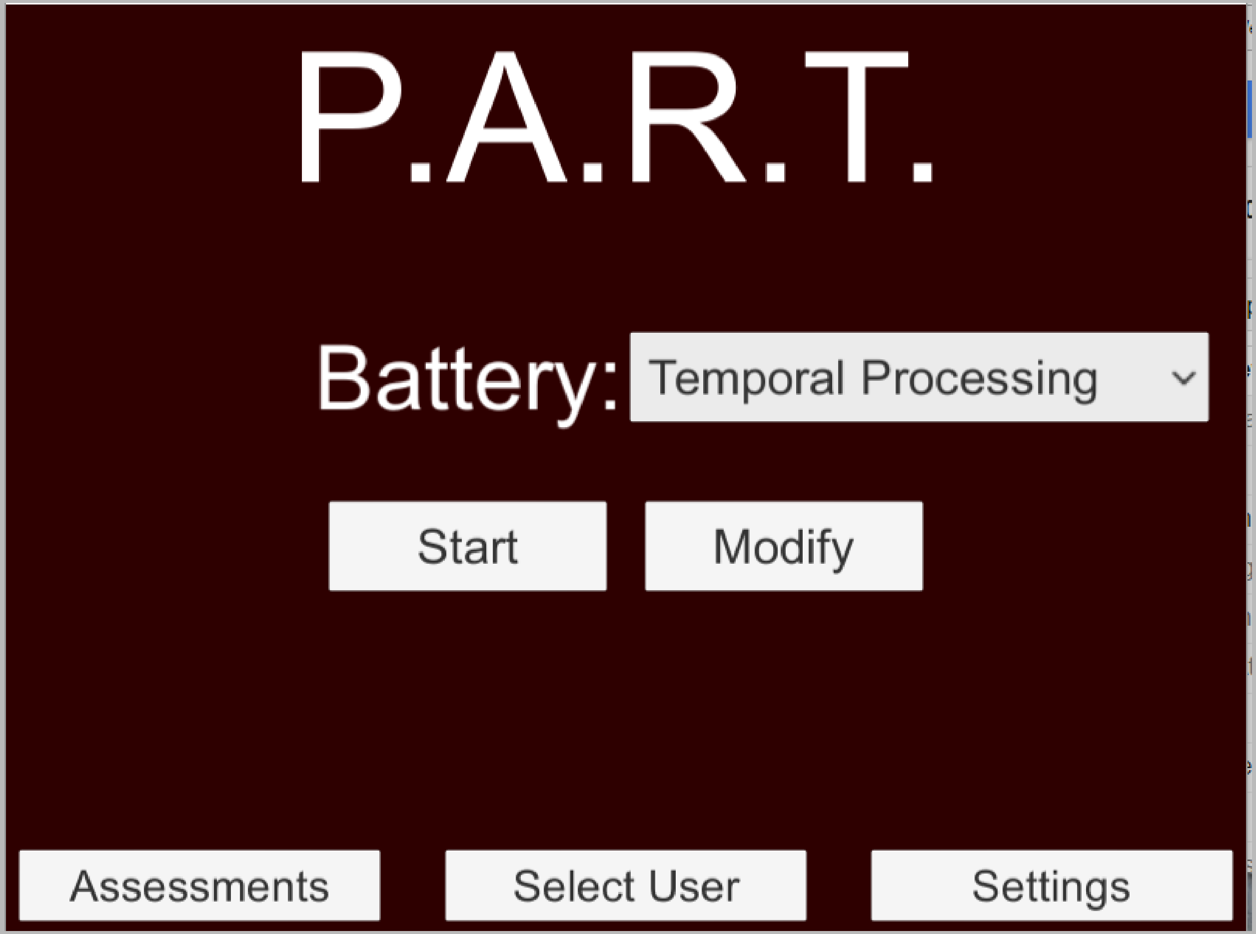
Large cross-sectional study of presbycusis reveals rapid progressive decline in auditory temporal acuity

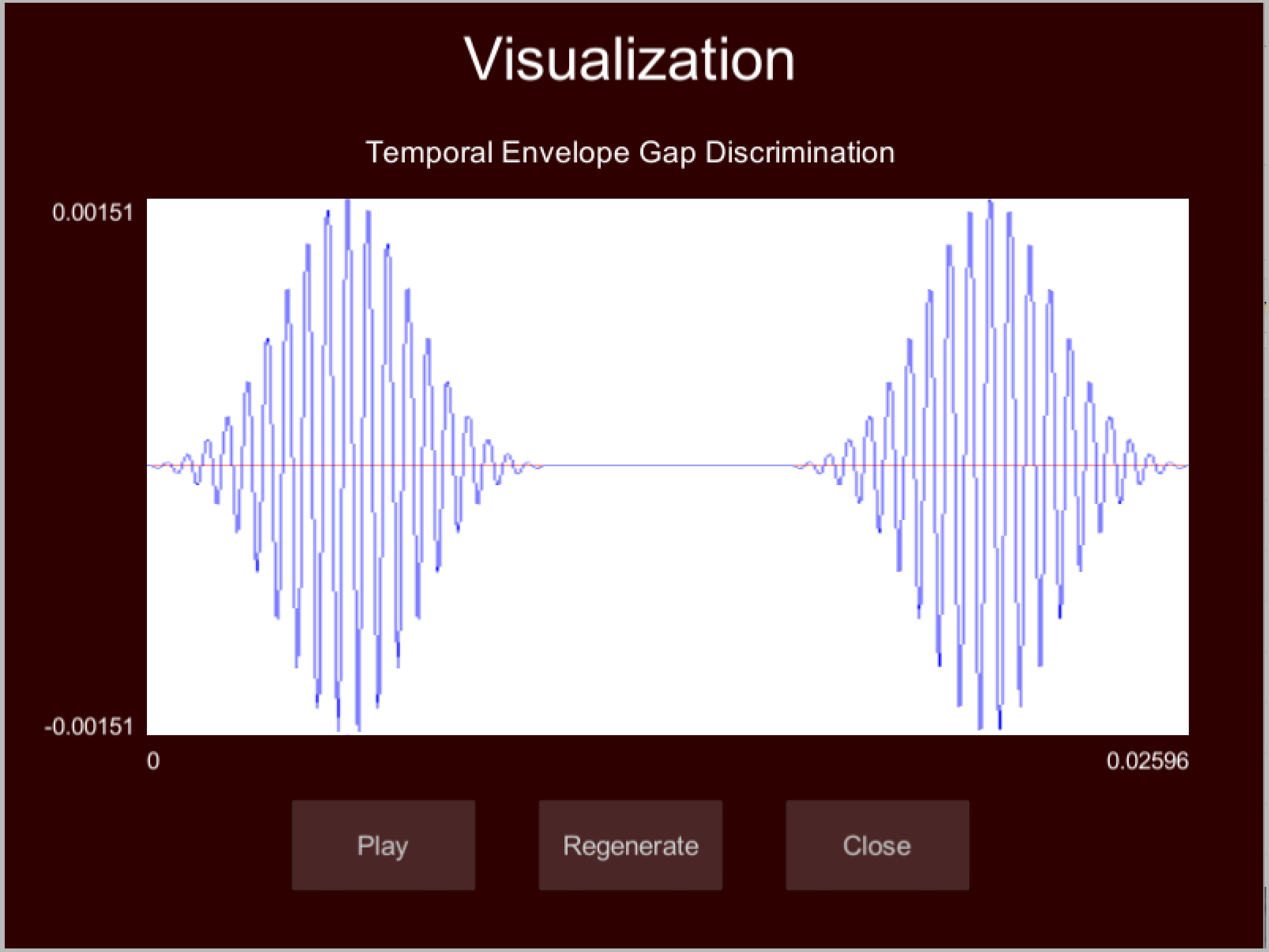
CrossMark

Erol J. Ozmeral*, Ann C. Eddins, D. Robert Frisina Sr, David A. Eddins

Department of Communication Sciences and Disorders, University of South Florida, Tampa, FL, USA

https://bgc.ucr.edu/games




Visualization
Temporal Envelope Gap Discrimination
0.00151
-0.00151
0
0.02596
Play
Regenerate
Close

Spectral and Spectrotemporal Modulation

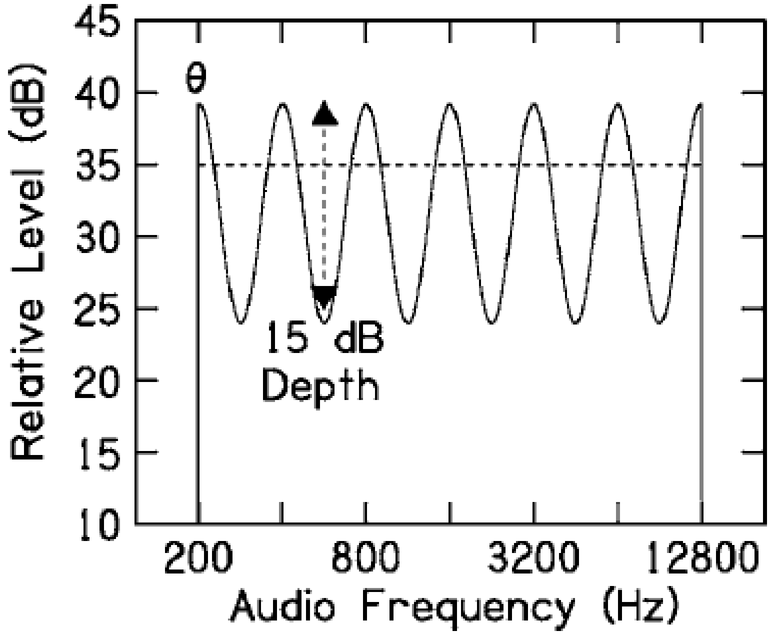
Sensitivity and Relationships with Speech in Noise

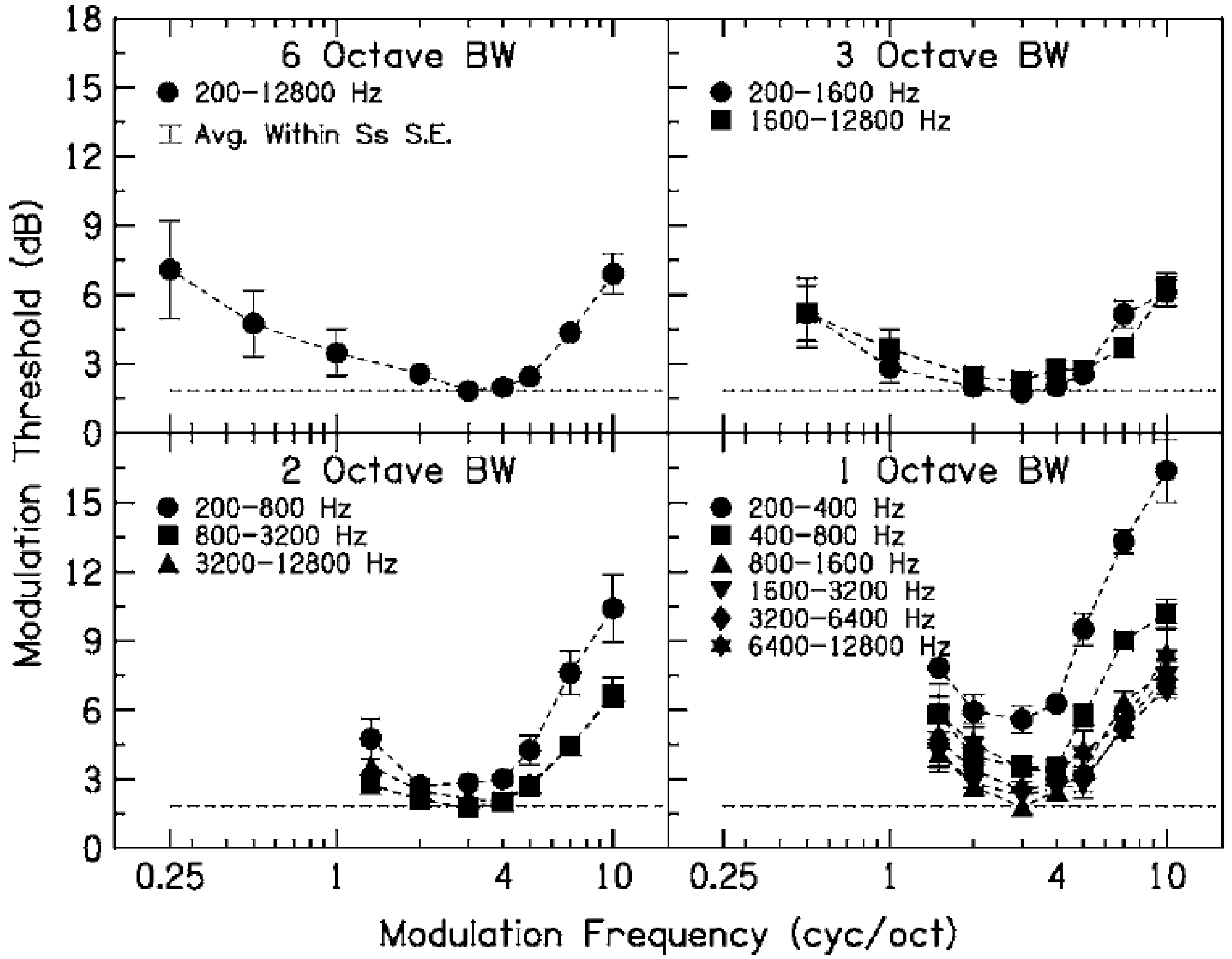
Spectral modulation detection as a function of modulation frequency, carrier bandwidth, and carrier frequency region

David A. Eddins[a)]
Department of Otolaryngology, University of Rochester, Rochester, NY 14642
and International Center for Hearing and Speech Research, Rochester Institute of Technology, Rochester, NY 14623

Eva M. Bero
Department of Audiology, University of Massachusetts Memorial Medical Center, 15 Belmont Street, Worchester, MA 01605

J. Acoust. Soc. Am. **121** (1), January 2007





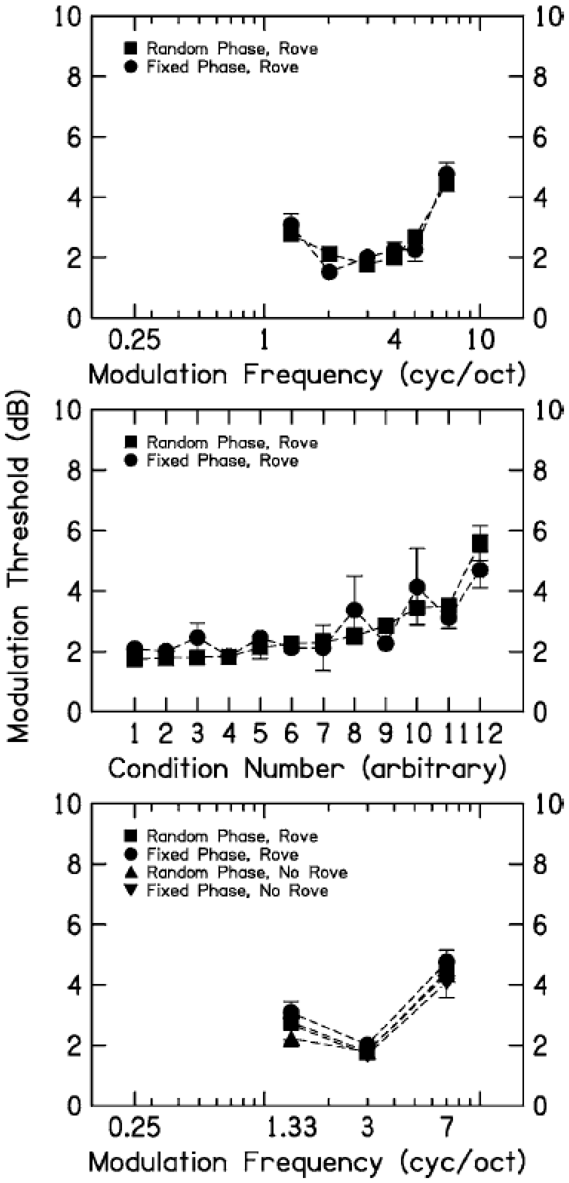


FIG. 4. Influence of spectral modulation phase. Upper panel shows SMTFs with random (squares) or fixed (circles) starting phase. In both cases, the overall level was randomized over a 10 dB range about the nominal stimulus level. Middle panel shows modulation detection thresholds for 3 cycles/octave in each of the 12 different carrier frequency/bandwidth conditions with random (squares) or fixed (circles) modulation phase. Lower panel shows abbreviated SMTFs for the four combinations of random level variation (ROVE or no-ROVE) and phase (random or fixed).

Spectral modulation detection as a function of modulation frequency, carrier bandwidth, and carrier frequency region

David A. Eddins[a]
Department of Otolaryngology, University of Rochester, Rochester, NY 14642 and International Center for Hearing and Speech Research, Rochester Institute of Technology, Rochester, NY 14623

Eva M. Bero
Department of Audiology, University of Massachusetts Memorial Medical Center, 15 Belmont Street, Worchester, MA 01605

J. Acoust. Soc. Am. **121** (1), January 2007

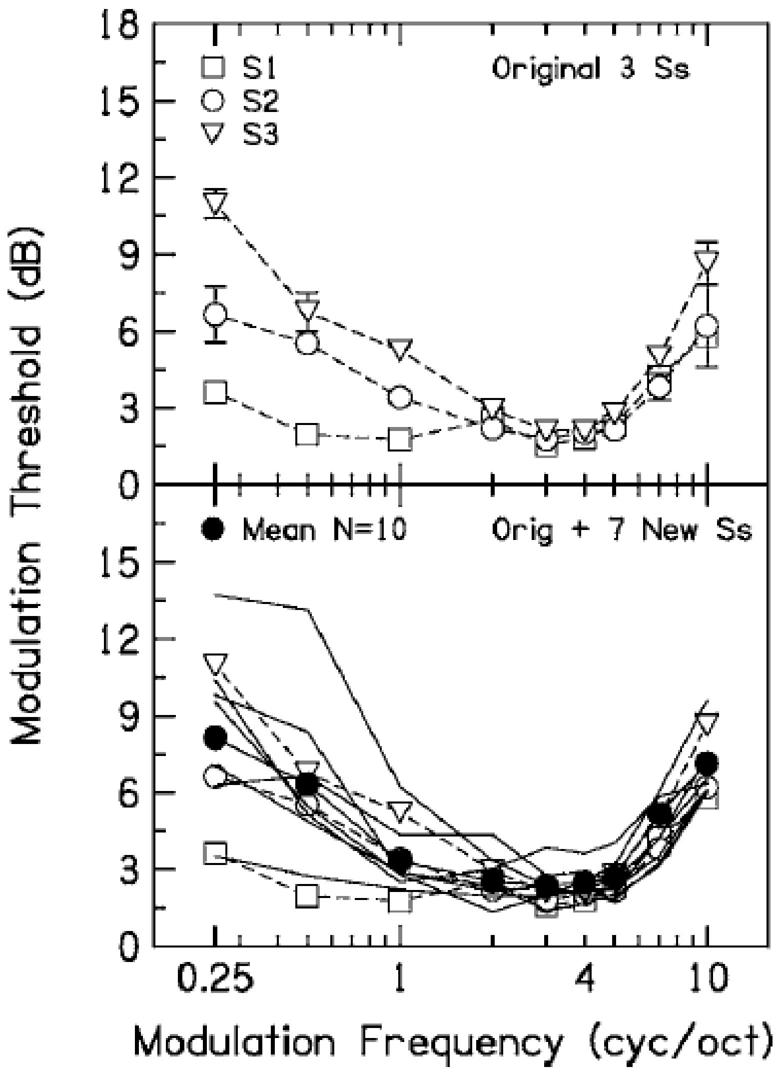
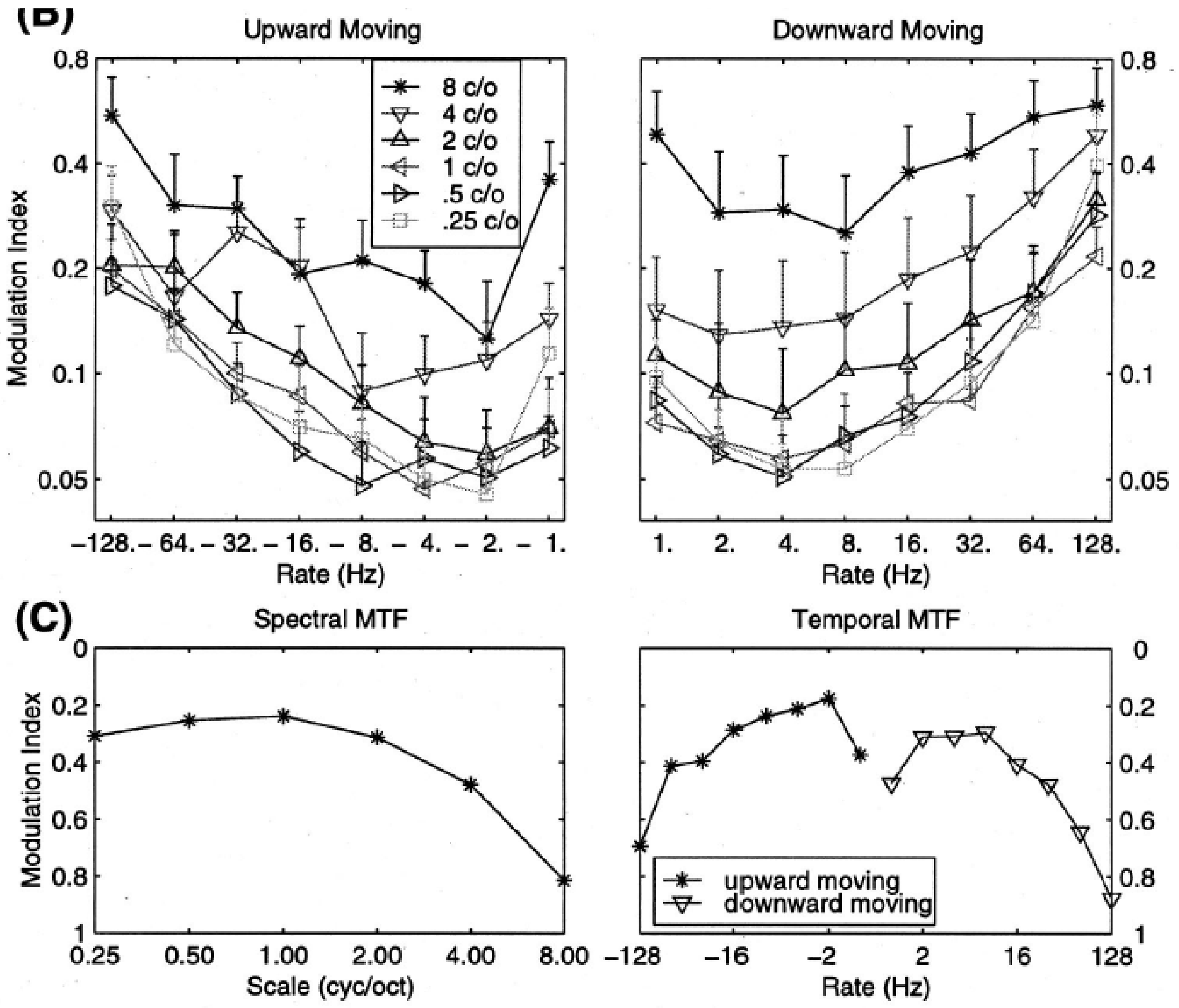


FIG. 3. Individual differences in spectral modulation detection. Upper panel shows individual SMTFs for the three original subjects in the 200–12 800 Hz carrier condition. Lower panel shows the same data (symbols) along with the data from seven new listeners (solid lines). The solid circles represent the mean thresholds across all ten listeners.

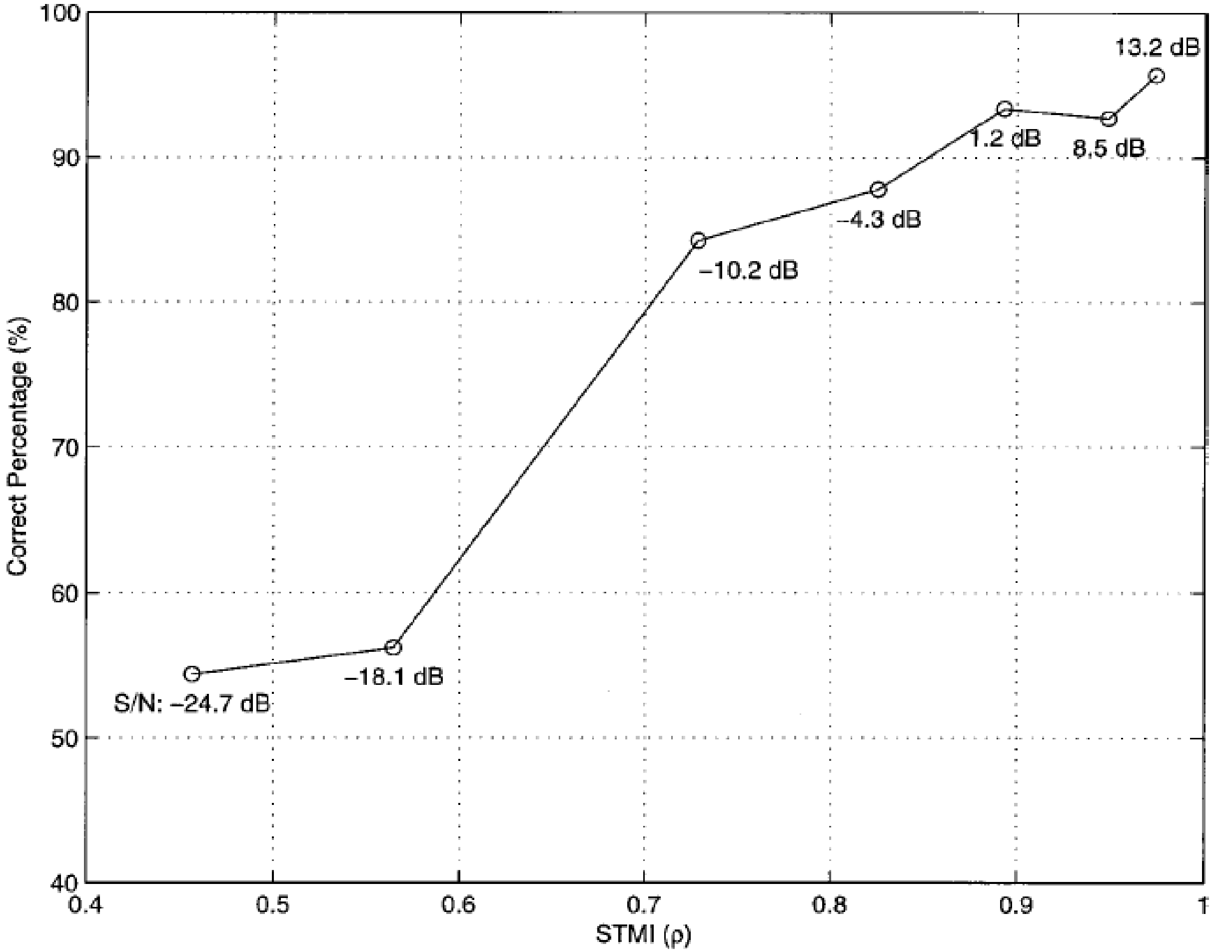
Spectro-temporal modulation transfer functions and speech intelligibility

Taishih Chi, Yujie Gao, Matthew C. Guyton, Powen Ru, and Shihab Shamma
Center for Auditory and Acoustics Research, Institute for Systems Research, Electrical Engineering Department, University of Maryland, College Park, Maryland 20742

2719 J. Acoust. Soc. Am. **106** (5), November 1999



Shamma and his colleagues have demonstrated that human sensitivity to spectrotemporal modulation is tuned in sensitivity in the same way that auditory cortical units are tuned and similarly to what is observed for spatial frequency in the visual system.



A computational model of the amount of STM present in a speech signal was shown to be related to the ability of human listeners to identify the speech.

Figure 8 illustrates the correspondence between the ρ [Eq. (14)] and the percentage of correct phonemes at each of the seven S/N conditions tested. The ρ evidently provides a fair average measure of the integrity of the phoneme percepts.

Spectro-temporal modulation transfer functions and speech intelligibility

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Center for Auditory and Acoustics Research, Institute for Systems Research, Electrical Engineering Department, University of Maryland, College Park, Maryland 20742

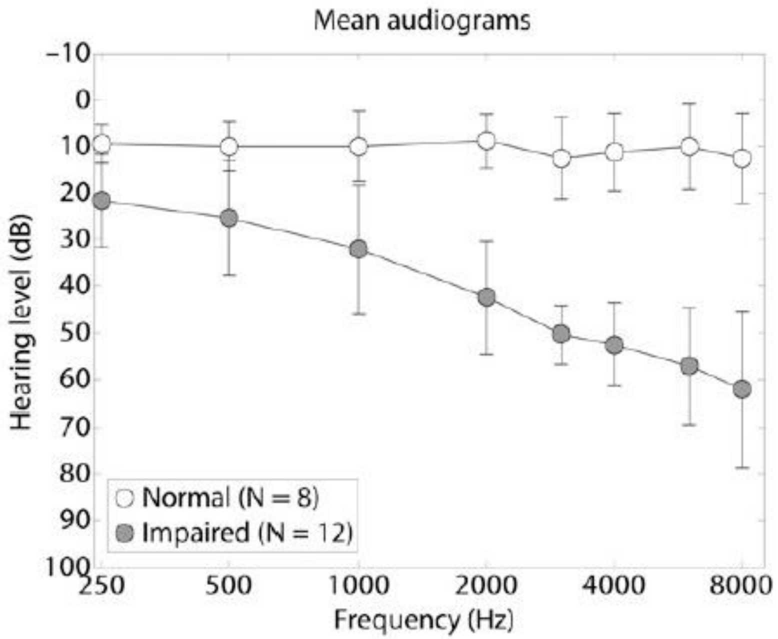
2719 J. Acoust. Soc. Am. **106** (5), November 1999

J Am Acad Audiol 24:293–306 (2013)

Spectrotemporal Modulation Sensitivity as a Predictor of Speech Intelligibility for Hearing-Impaired Listeners

DOI: 10.3766/jaaa.24.4.5

Joshua G.W. Bernstein*
Golbarg Mehraei†
Shihab Shamma‡
Frederick J. Gallun§
Sarah M. Theodoroff§
Marjorie R. Leek§



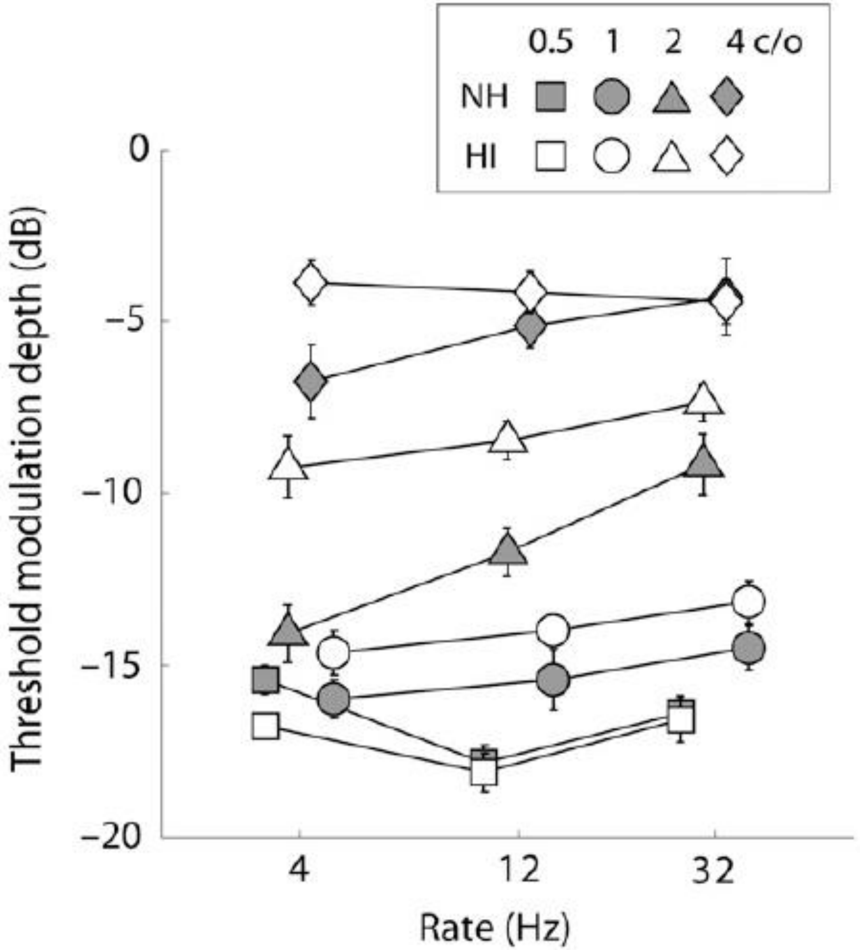


Figure 3. Group-mean STM detection thresholds averaged across upward- and downward-moving conditions. Error bars indicate ±1 SE across listeners in each group.

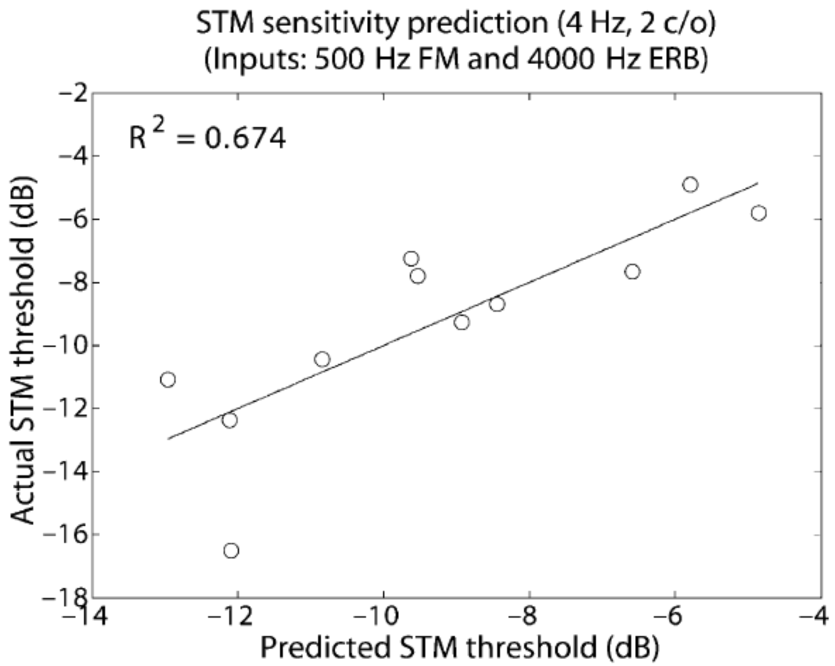


Figure 4. Actual STM detection thresholds for individual HI listeners (for the 4 Hz, 2 c/o condition, averaged across upward- and downward-moving ripples) are plotted as a function of the threshold predicted by a linear regression model with the 500 Hz FM detection threshold and 4000 Hz ERB as inputs.

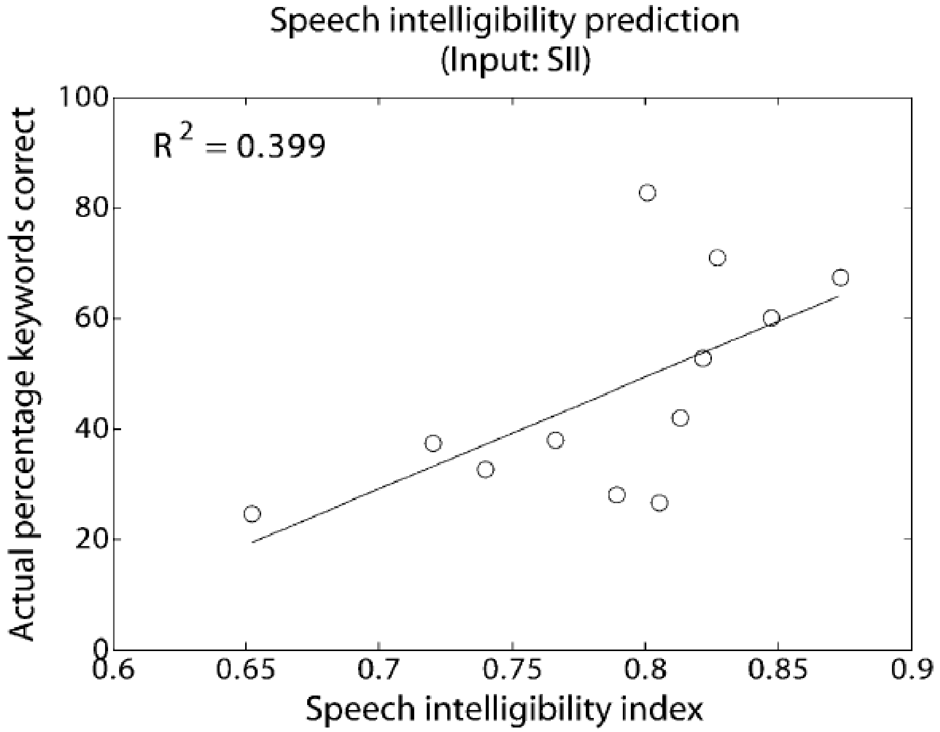


Figure 5. Speech reception performance for sentence keywords presented in stationary noise at a 0 dB SNR is plotted as a function of the audiogram-based SII for individual HI listeners.

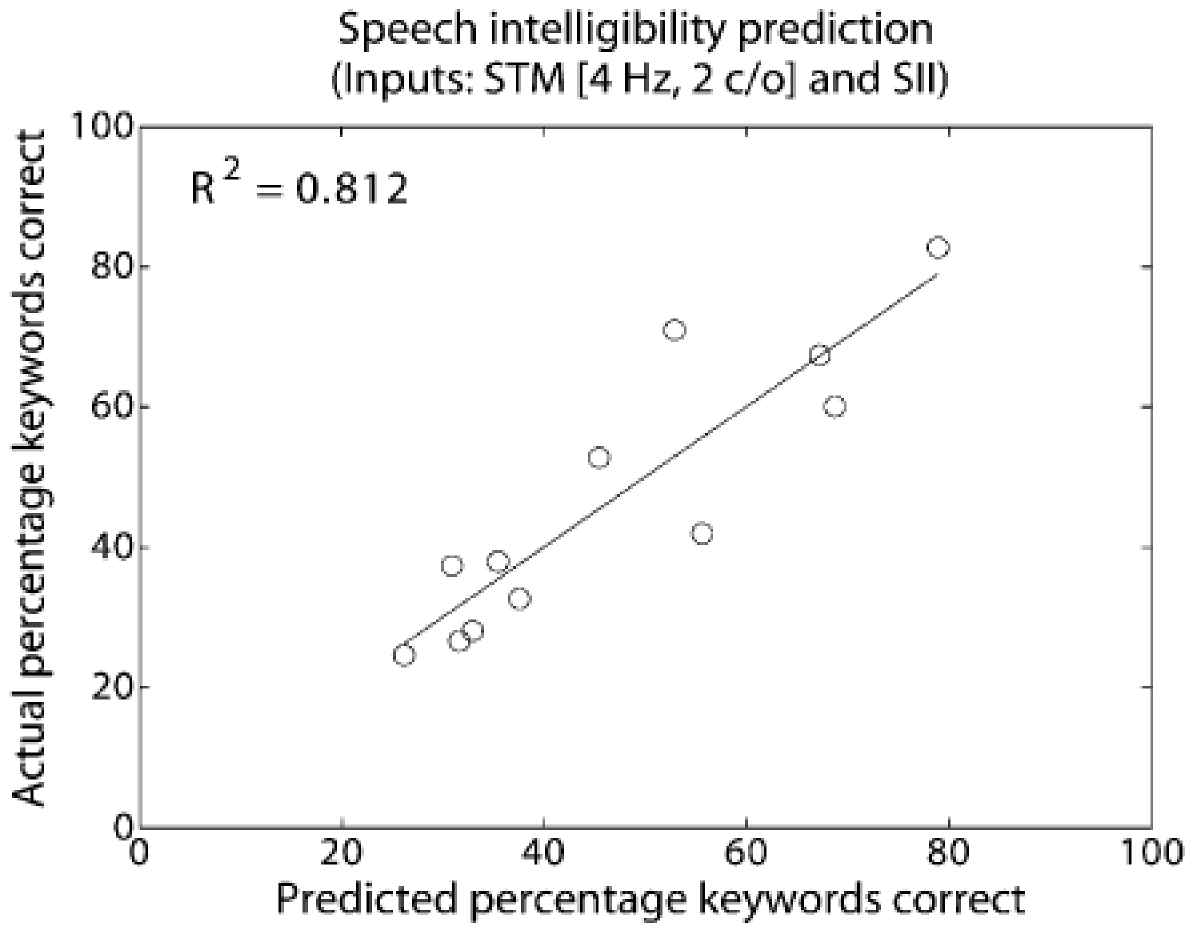
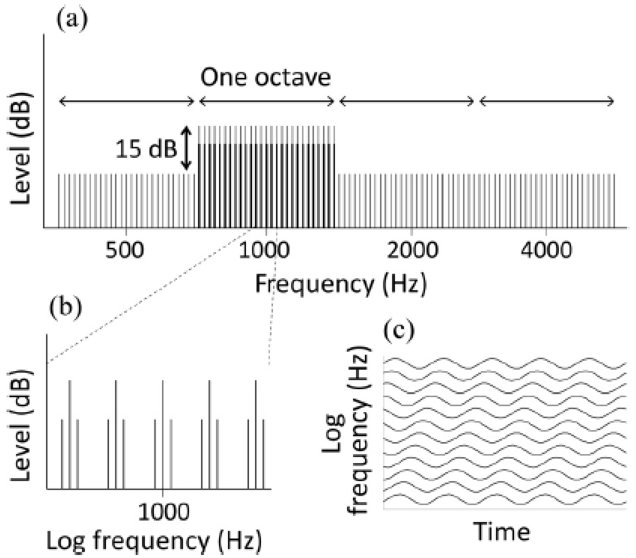
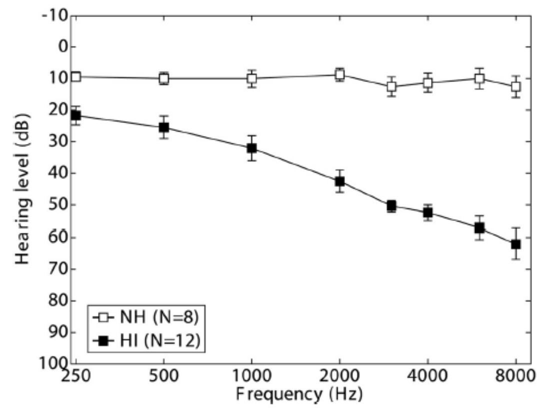
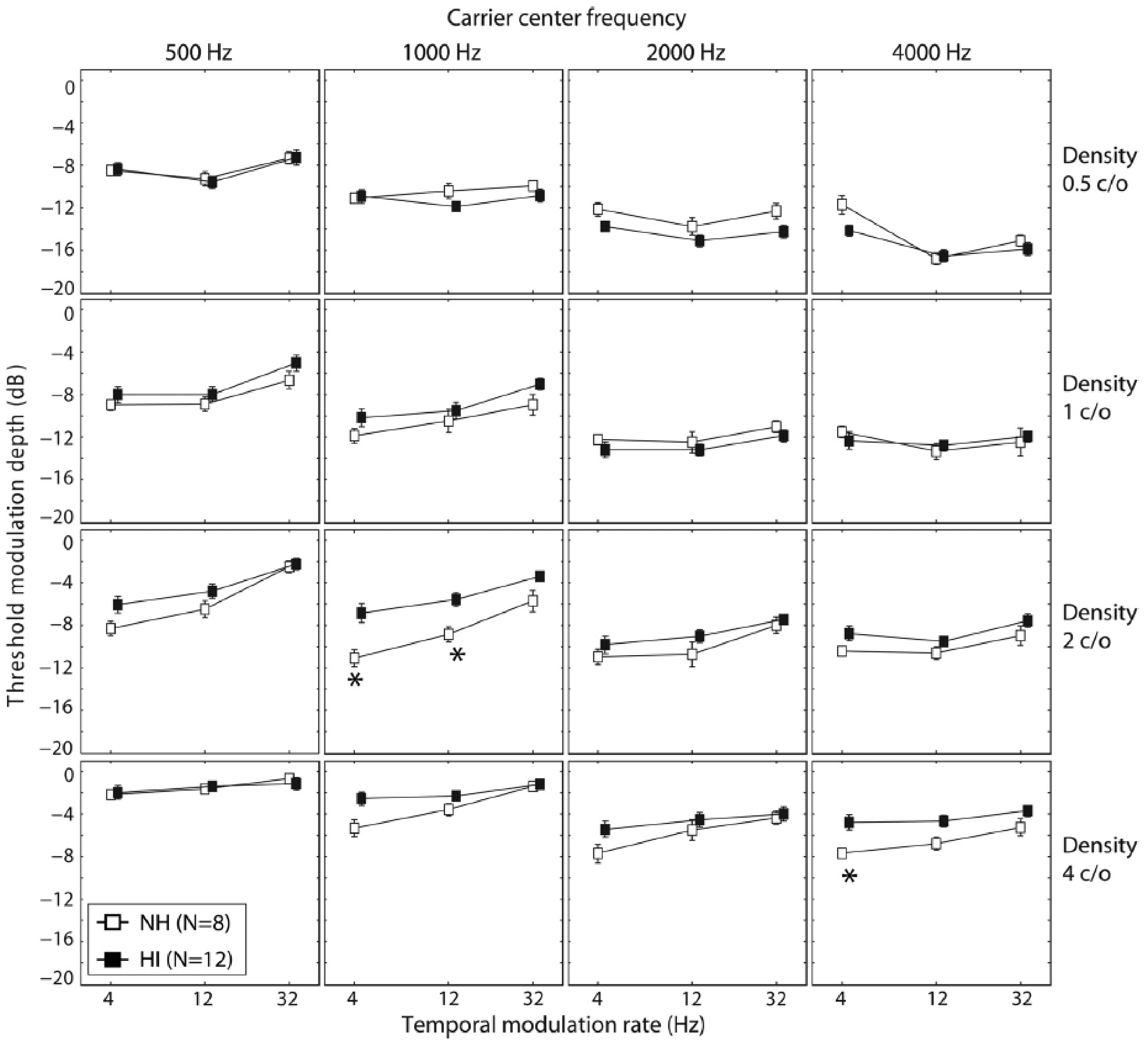


Figure 6. Actual speech intelligibility is plotted as a function of the intelligibility predicted by a linear regression model with SII and STM sensitivity (4 Hz, 2 c/o) as inputs.

A relationship was observed between STM sensitivity and the FM detection and frequency-selectivity tests that are thought to target the mechanisms underlying the detection of STM. Therefore, another possible avenue would be to measure these more basic psychophysical attributes instead of STM sensitivity. From a clinical perspective, it would be preferable to use the STM metric because it contains information about these underlying mechanisms within a single test, reducing the number of psychophysical attributes that would need to be measured for a given individual. Most importantly, the STM metric was more closely correlated to speech perception than were these other measures, perhaps because it is more similar to a speech signal, with a wide bandwidth and modulations that simulate those occurring naturally in speech.







Spectrotemporal modulation sensitivity for hearing-impaired listeners: Dependence on carrier center frequency and the relationship to speech intelligibility

Golbarg Mehraei
Program in Speech and Hearing Bioscience and Technology, Harvard University–Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Frederick J. Gallun and Marjorie R. Leek
VA RR&D National Center for Rehabilitative Auditory Research, Portland VA Medical Center, Portland, Oregon 97239

Joshua G. W. Bernstein[a)]
National Military Audiology and Speech Pathology Center, Walter Reed National Military Medical Center, Bethesda, Maryland 20889

J. Acoust. Soc. Am. 136 (1), July 2014

Spectrotemporal modulation sensitivity for hearing-impaired listeners: Dependence on carrier center frequency and the relationship to speech intelligibility

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J. Acoust. Soc. Am. **136** (1), July 2014

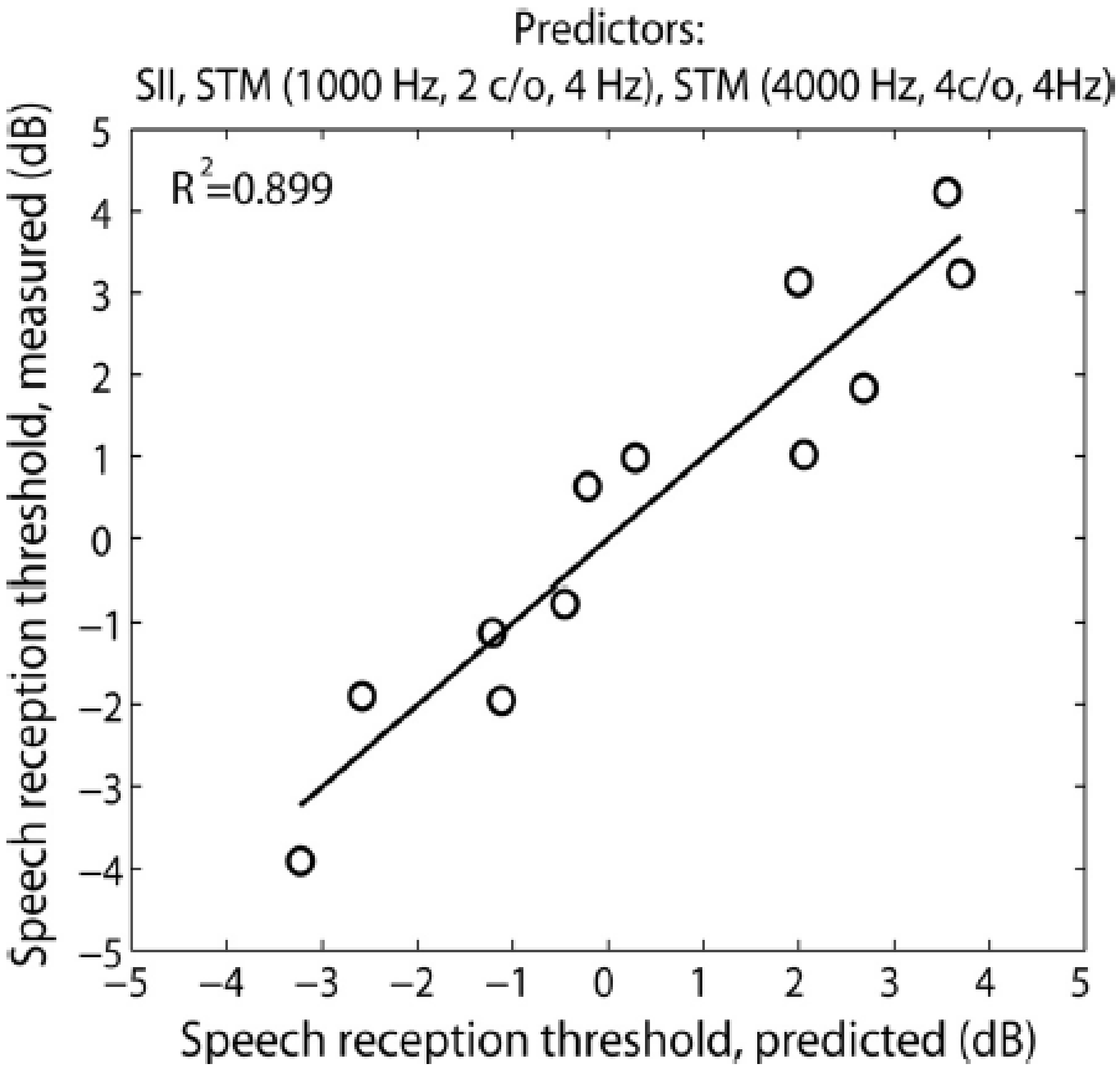
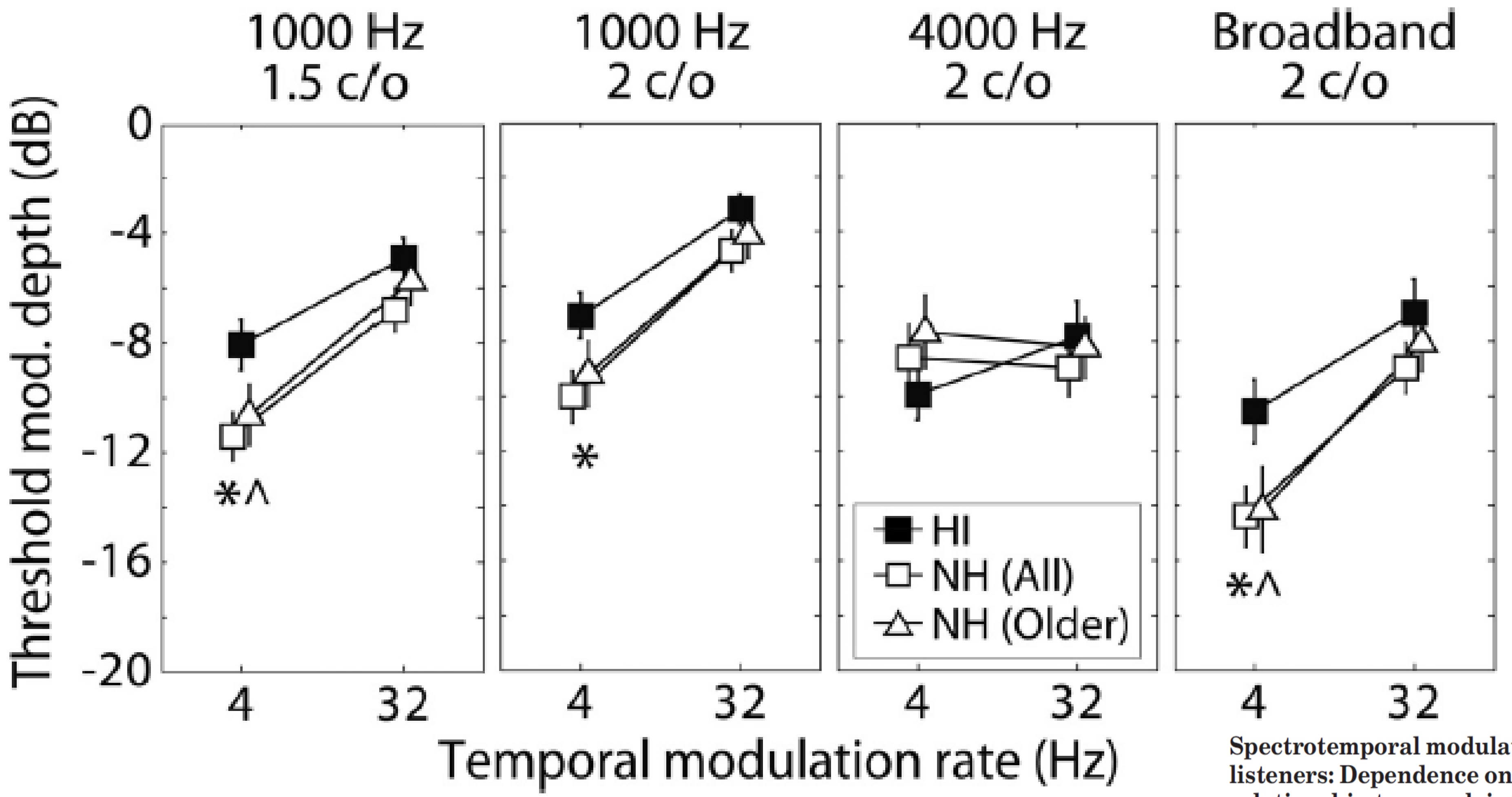


FIG. 5. The SRT_{50} measured for individual HI subjects is plotted as a function of the SRT_{50} predicted by a linear regression model with three inputs: the SII and STM sensitivity for the [4 Hz, 4 c/o, 4000 Hz] and [4 Hz, 2 c/o, 1000 Hz] conditions.



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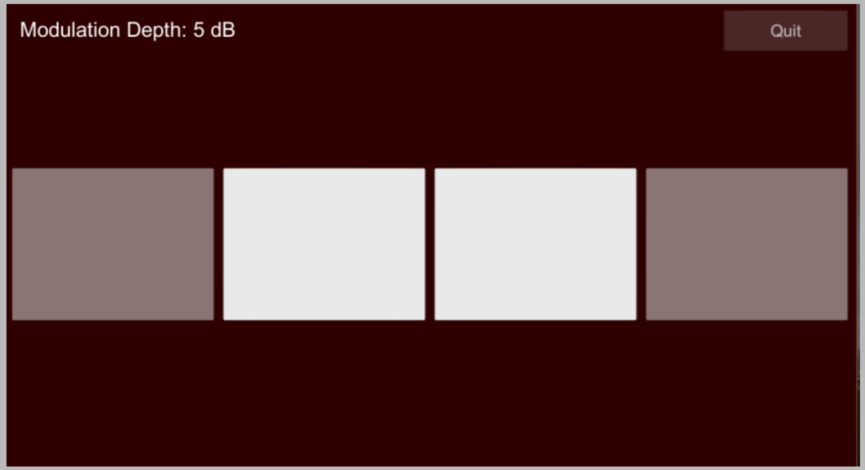
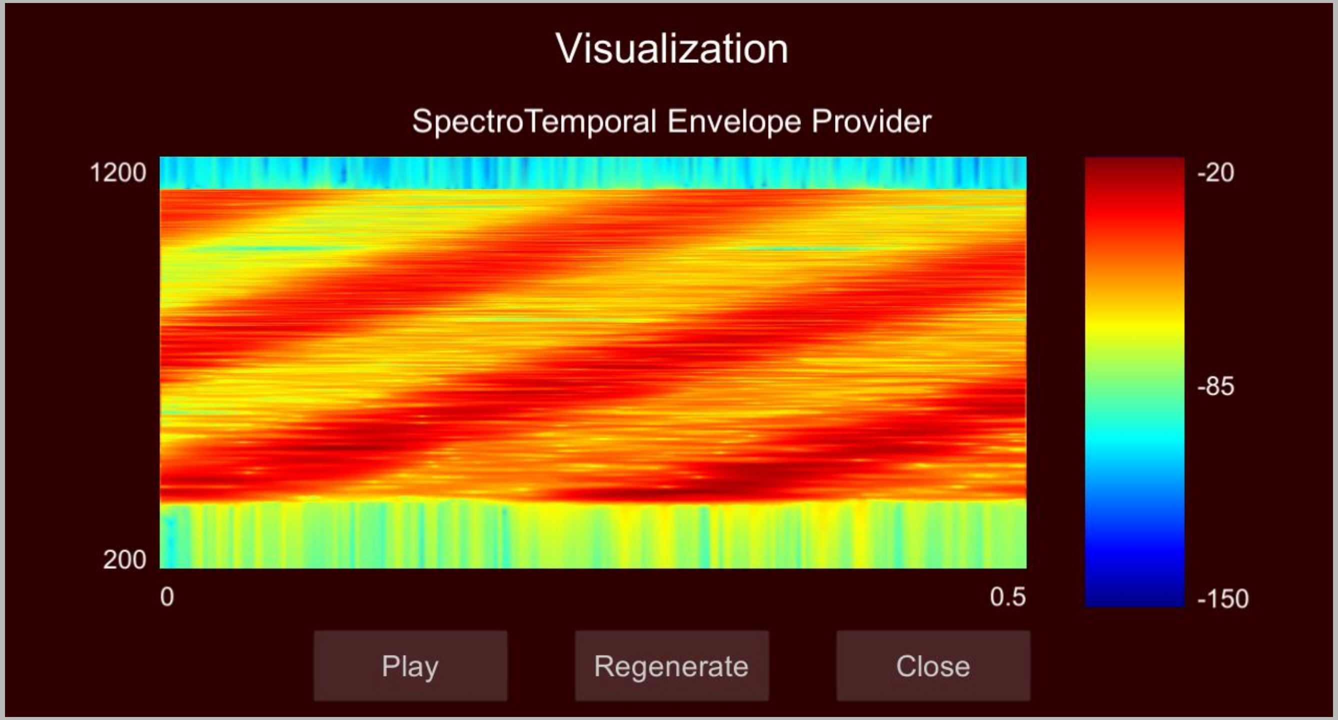
J. Acoust. Soc. Am. 136 (1), July 2014



https://bgc.ucr.edu/games



Binaural Processing

Dichotic Detection of Frequency Modulation

Using individual differences to test the role of temporal and place cues in coding frequency modulation

Kelly L. Whiteford[a] and Andrew J. Oxenham
Department of Psychology, University of Minnesota, Minneapolis, Minnesota 55455, USA

J. Acoust. Soc. Am. **138** (5), November 2015

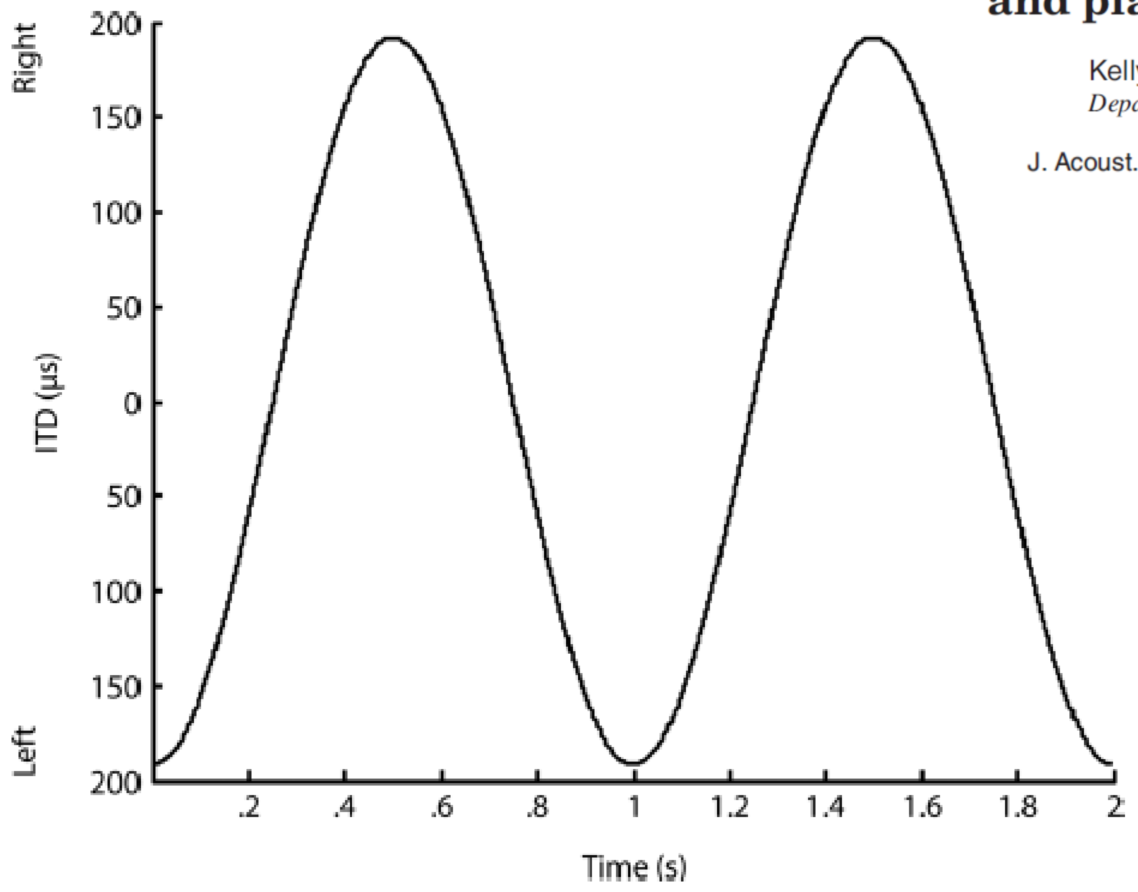


FIG. 1. Example of dynamic ITDs as a function of time when $\Delta f = 0.06\%$ and $f_m = 1$ Hz. The black line corresponds to the ITD at each point in time for a dichotic FM tone when $\Delta f = 0.06\%$, the average slow dichotic FMDL across all subjects. Note that whether the tone began as a left-lateralized percept or a right-lateralized percept depends on the starting phase of the modulator.

Binaural sensitivity can be measured either with clicks or tone bursts or by creating a time-varying interaural time difference using frequency modulated (FM) stimuli

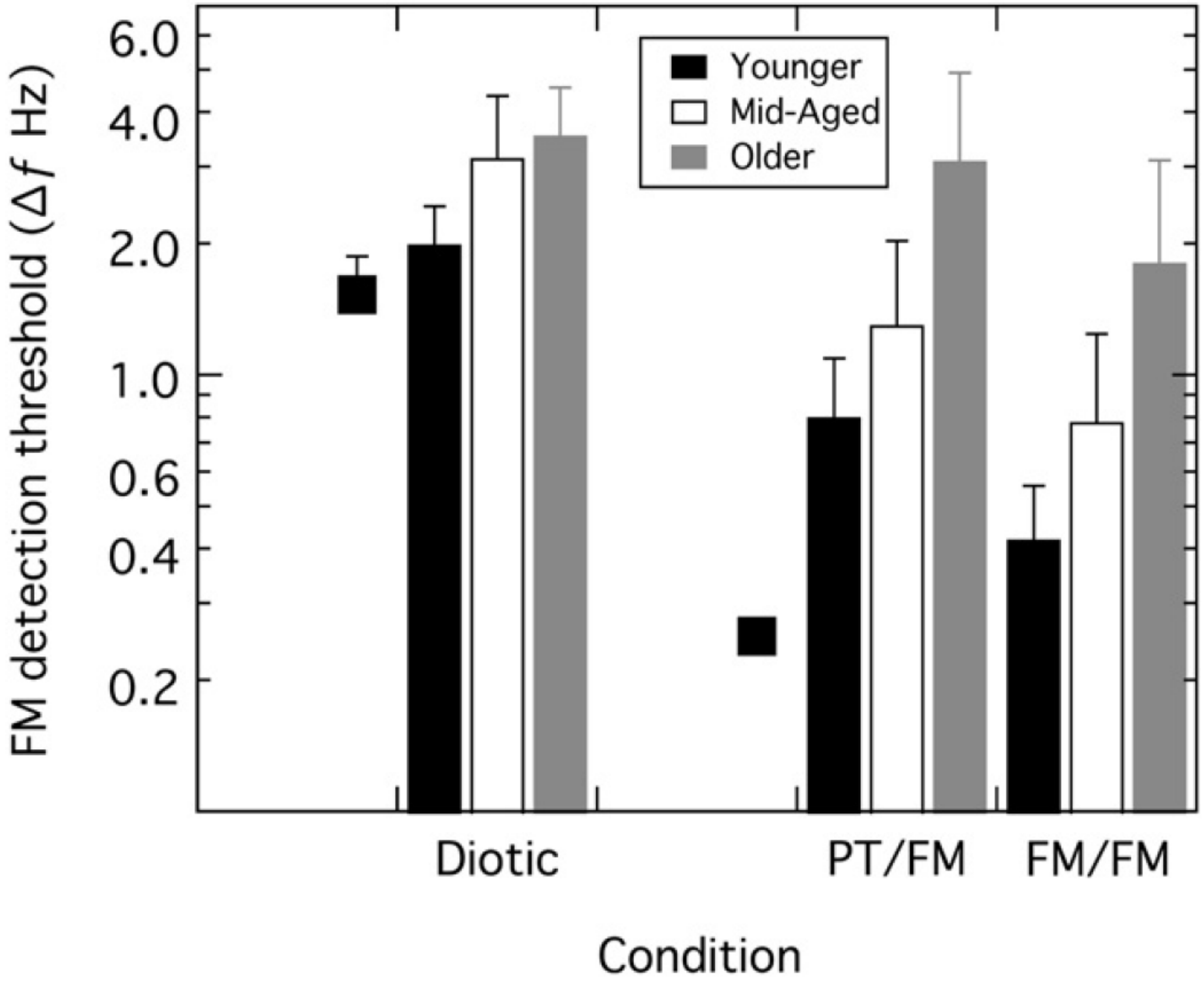


Fig. 3. FM detection thresholds for the three binaural conditions: *Diotic*, *Dichotic PT/FM*, and *Dichotic FM/FM*. Bar shading indicates age group as shown by the key. Error bars show 1 standard deviation. Filled squares show data from Witton et al. (2000).

Frequency modulation detection as a measure of temporal processing: Age-related monaural and binaural effects

John H. Grose*, Sara K. Mamo

Dept. Otolaryngology, Head & Neck Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC 27519, USA

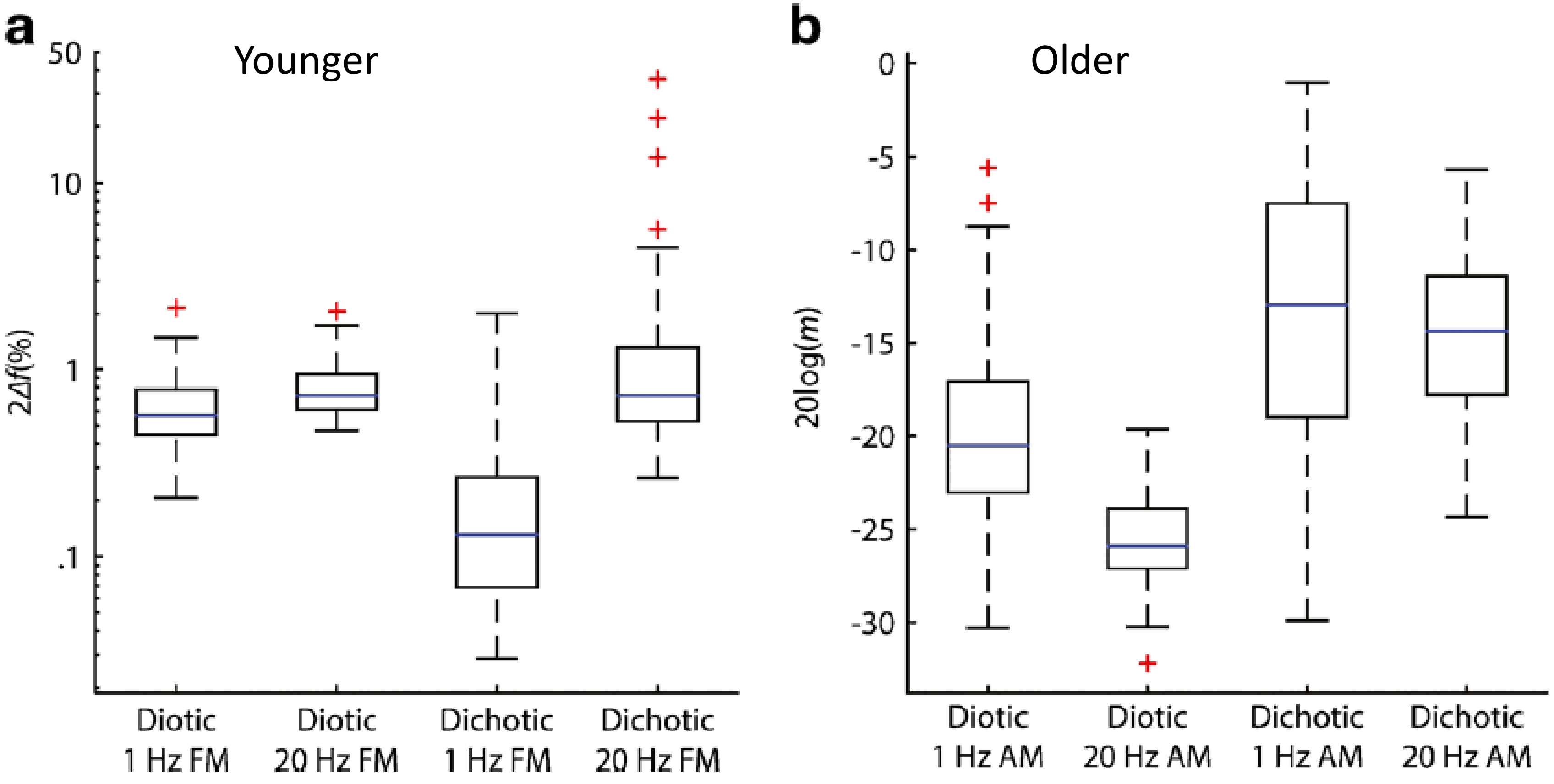
Hearing Research 294 (2012) 49–54

Assessing the Role of Place and Timing Cues in Coding Frequency and Amplitude Modulation as a Function of Age

Kelly L. Whiteford,[1] Heather A. Kreft,[1] and Andrew J. Oxenham[1]

[1]Department of Psychology, University of Minnesota, N218 Elliott Hall, 75 East River Rd, Minneapolis, MN 55455, USA

JARO 18: 619–633 (2017)



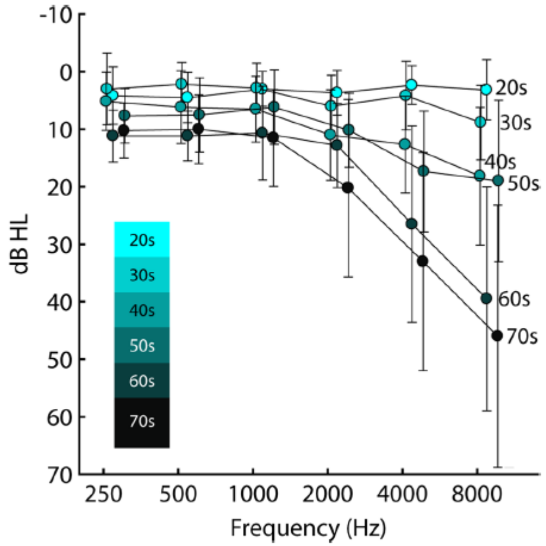
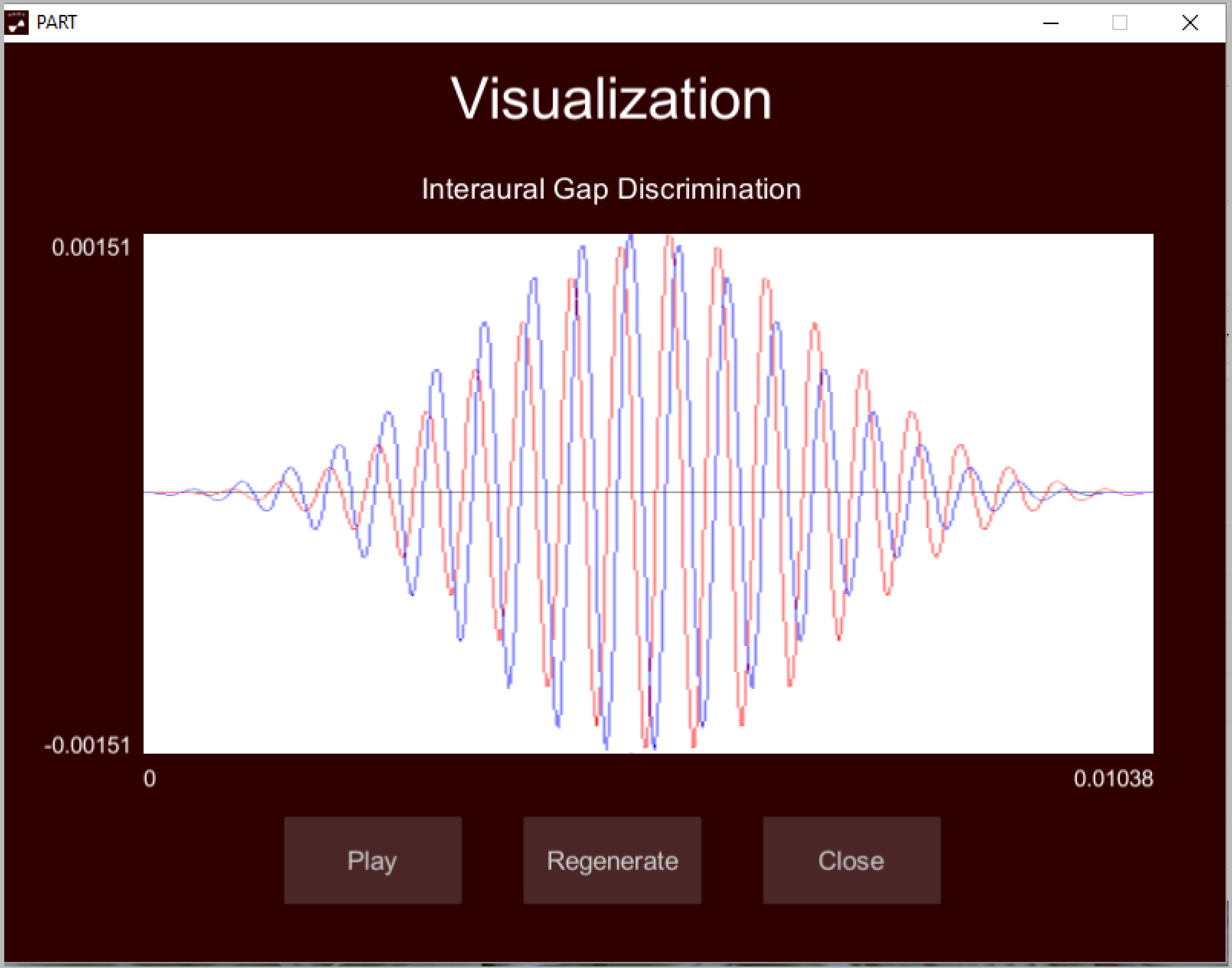


FIG. 1. Average audiometric thresholds for each decade of age. Error bars represent ±1 standard deviation. Symbols are offset around the octave frequencies for clarity.



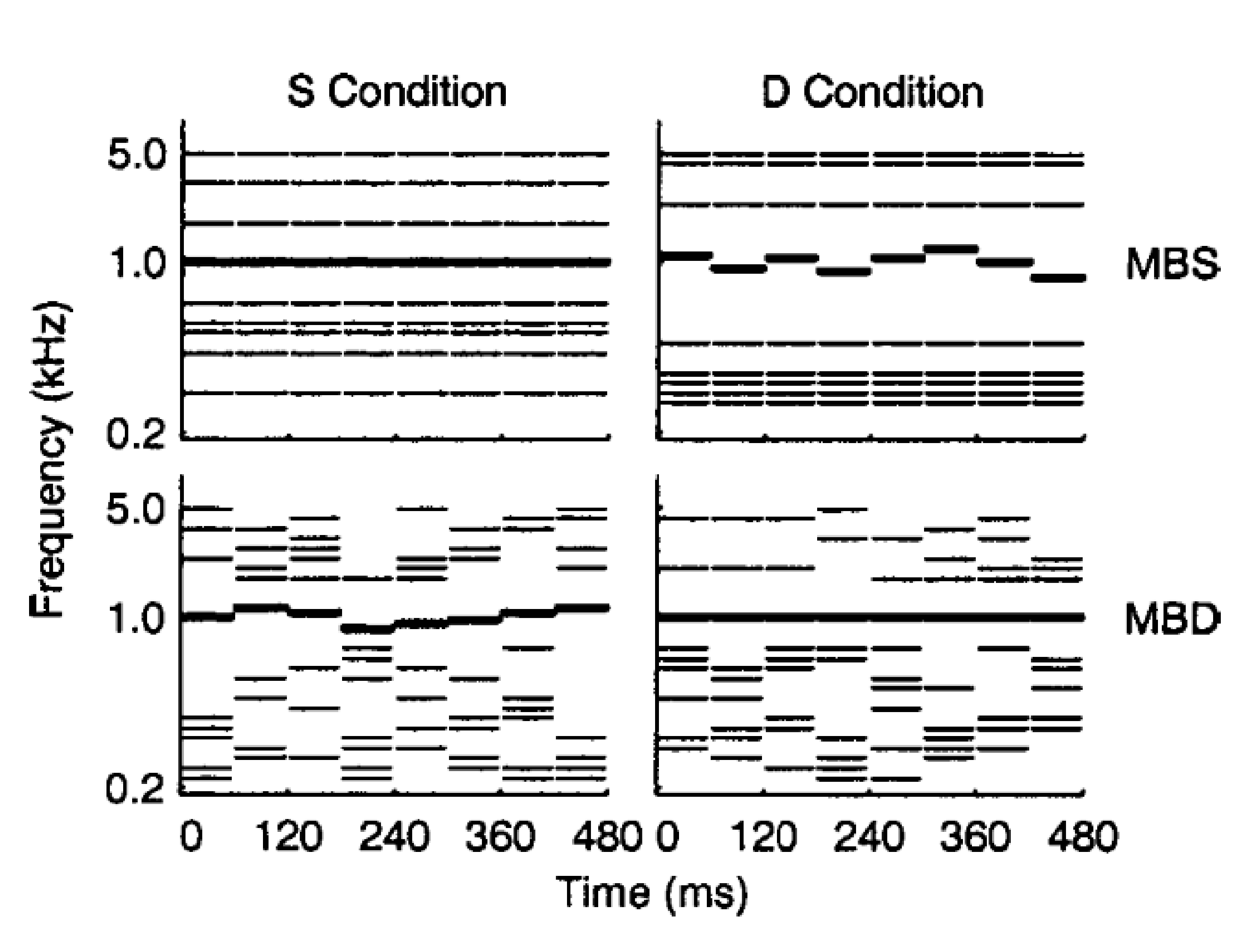
PART
Visualization
Interaural Gap Discrimination
0.00151
-0.00151
0
0.01038
Play
Regenerate
Close

PART 5

Steps Forward

Tests of Informational Masking: Tones and Speech

Informational Masking with Tones
Target/Masker similarity
(Kidd et al., 1994)



JARO 03: 107–119 (2001)
DOI: 10.1007/s1016200210095

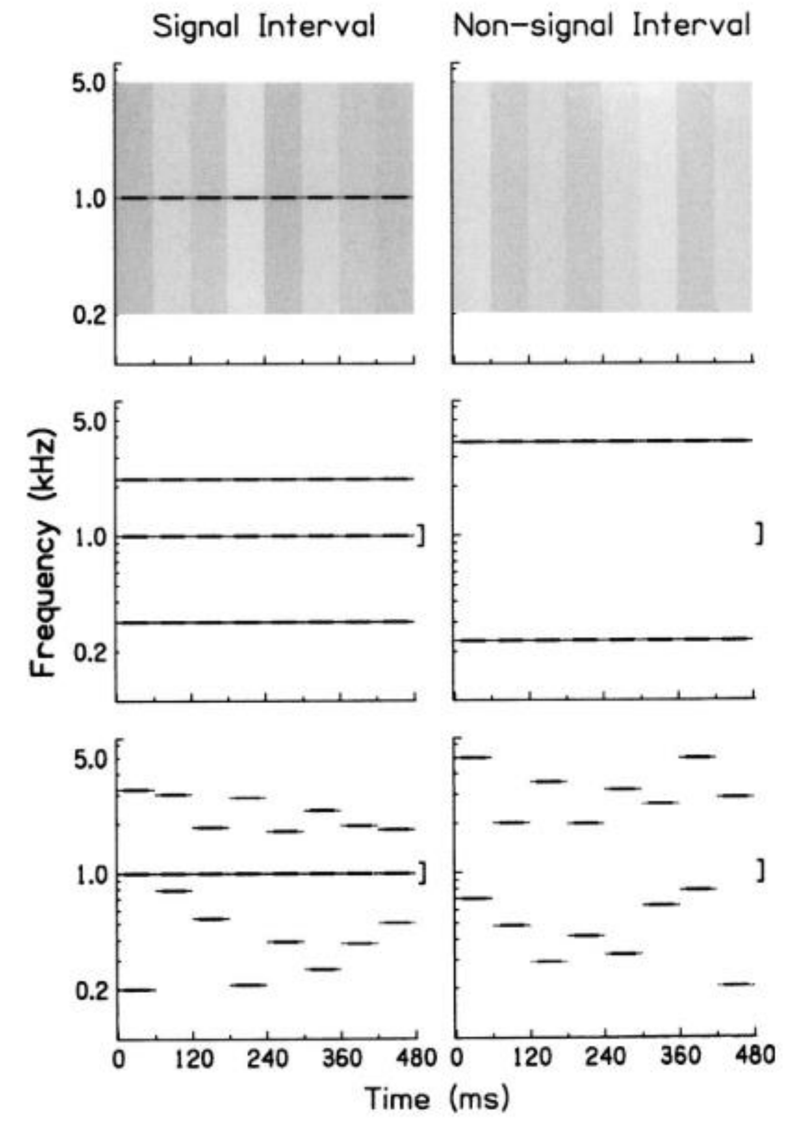
JARO
Journal of the Association for Research in Otolaryngology

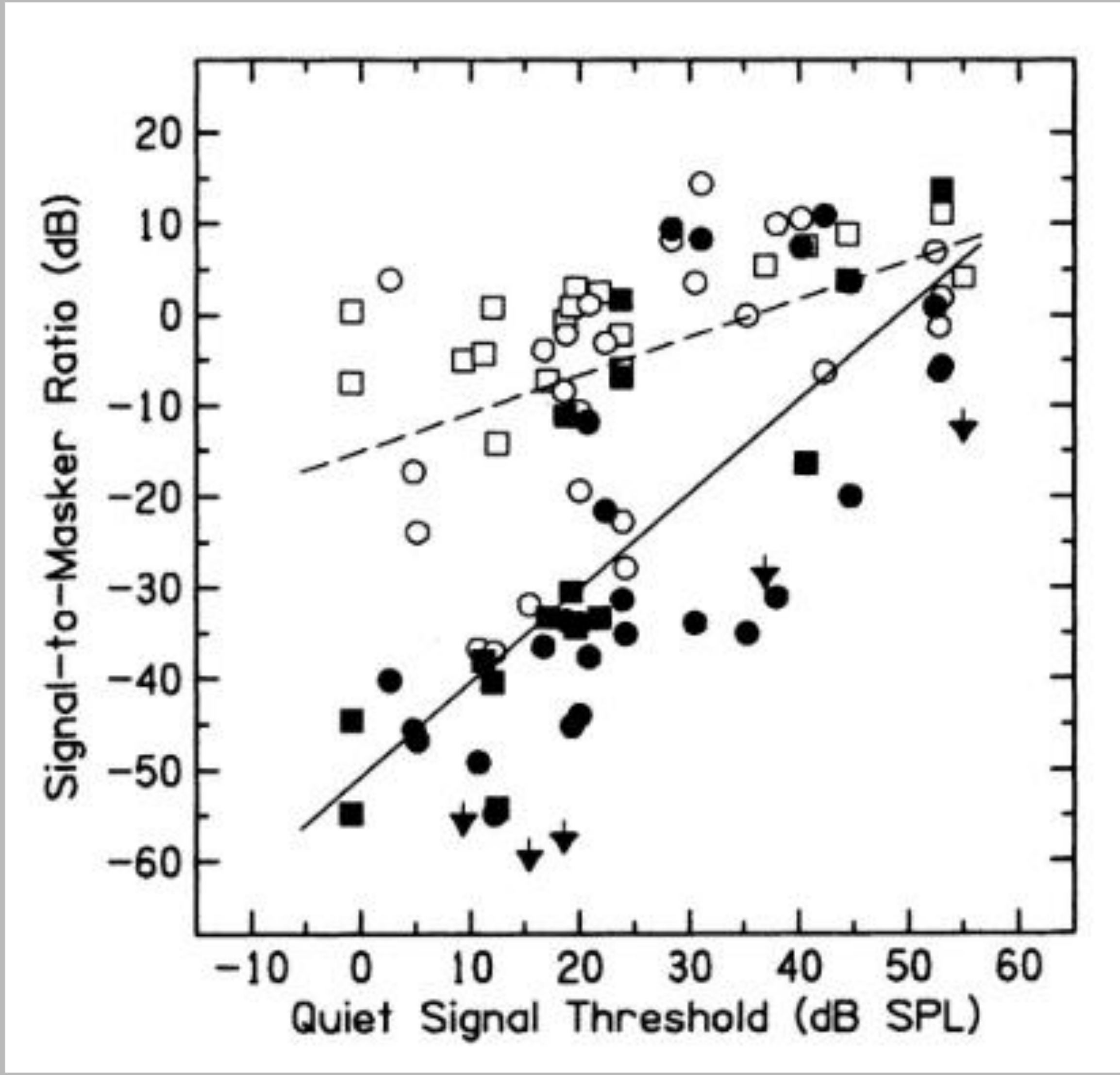
Informational Masking in Listeners with Sensorineural Hearing Loss

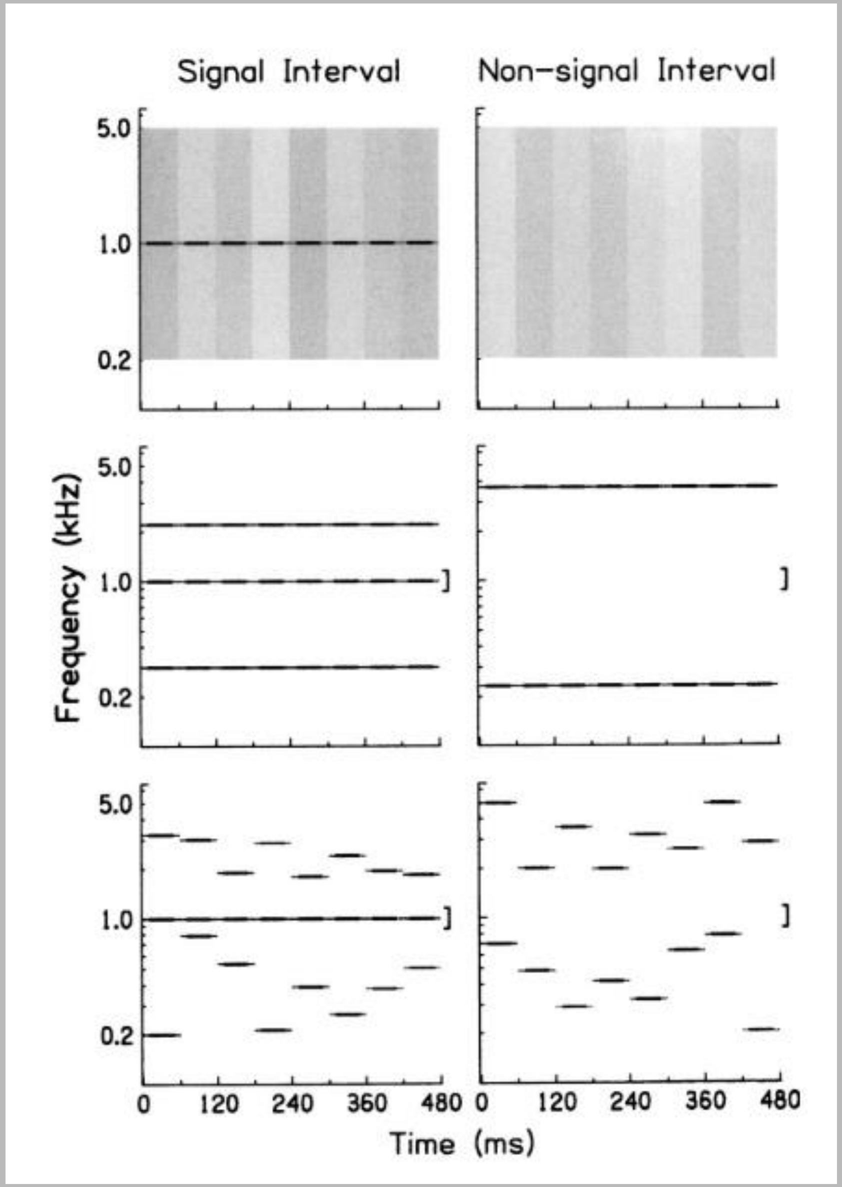
Gerald Kidd, Jr.,[1] Tanya L. Arbogast,[1,2] Christine R. Mason,[1] and Michael Walsh[2]

[1]*Department of Communication Disorders and Hearing Research Center, Boston University, Boston, MA 02215, USA*
[2]*Audiology/Speech Pathology Service, VA Boston Healthcare System, Boston, MA 02130, USA*

Received: 8 December 2000; Accepted: 17 July 2001; Online publication: 3 October 2001




Signal-to-Masker Ratio (dB)
20
10
0
-10
-20
-30
-40
-50
-60
-10
0
10
20
30
40
50
60
Quiet Signal Threshold (dB SPL)


Signal Interval
Non-signal Interval
5.0
1.0
0.2
Frequency (kHz)
0
120
240
360
480
Time (ms)

A speech corpus for multitalker communications research

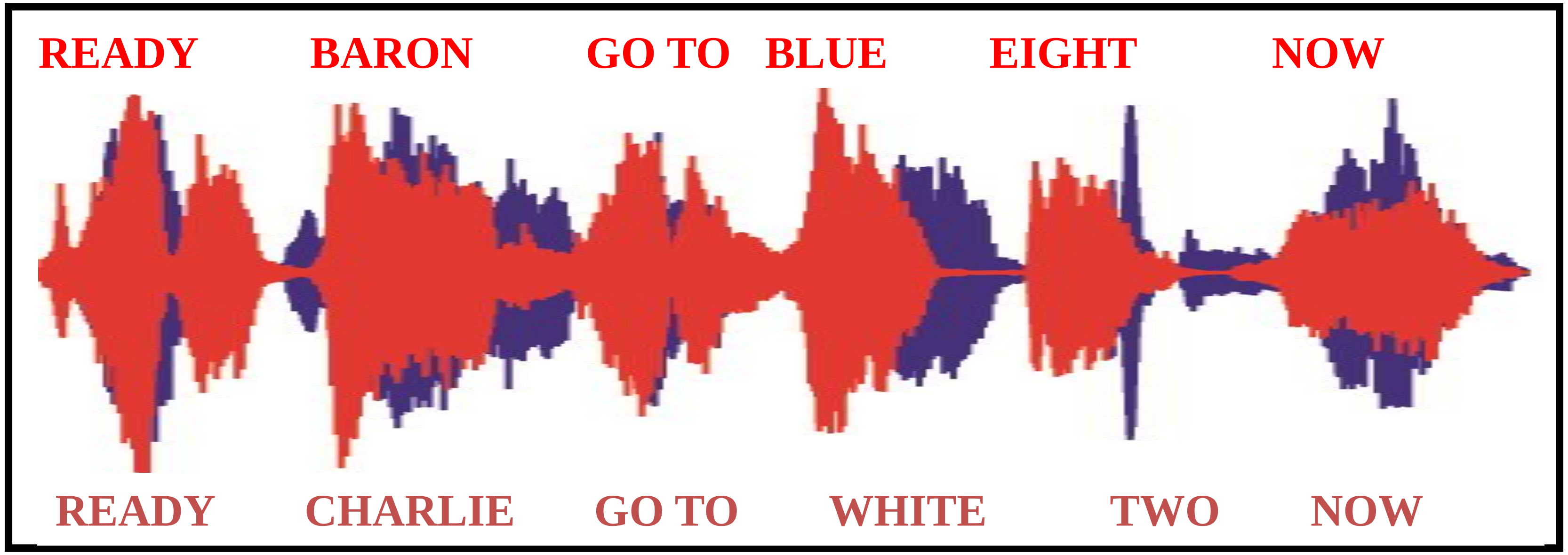
Robert S. Bolia, W. Todd Nelson, and Mark A. Ericson
Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433

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."

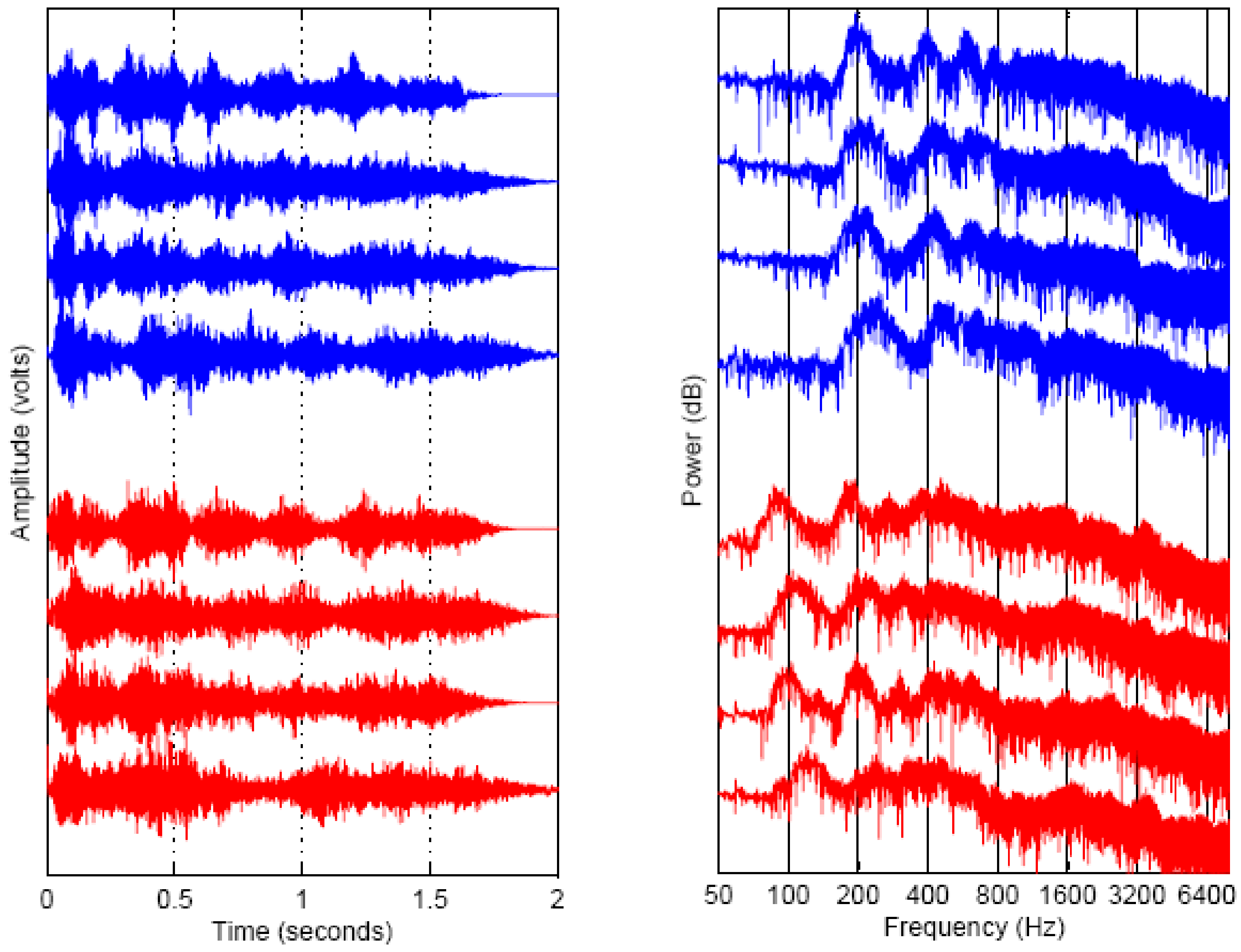
32 possible keyword combinations: 4 colors (red, white, green, blue) and
8 numbers (1 to 8)
8 different callsigns (Baron, Charlie, Hopper, Arrow, Ringo,.
8 talkers: 4 male and 4 female.



All Sentences

Female Talkers in blue (top four)

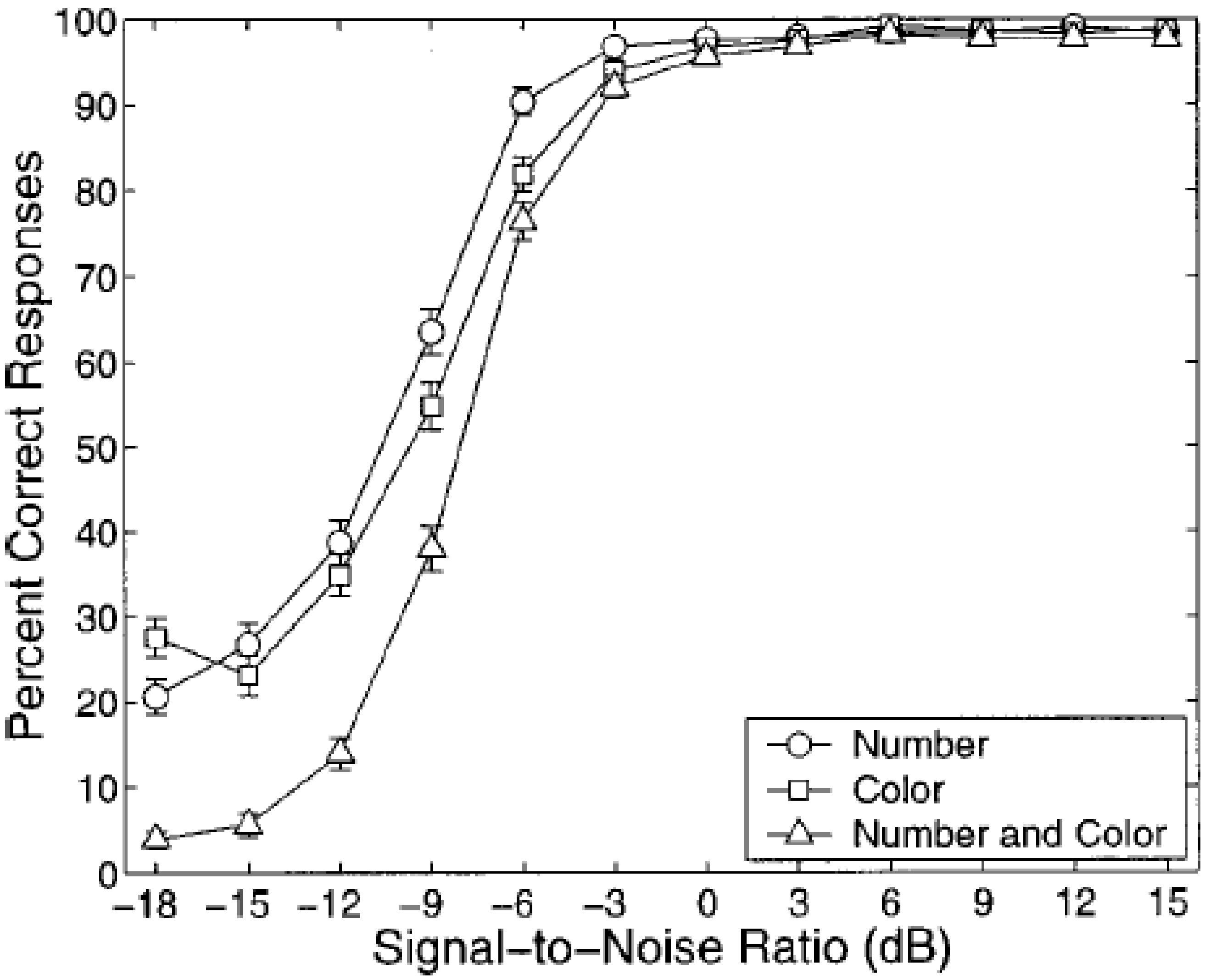
Male Talkers in red (bottom four)



Evaluation of speech intelligibility with the coordinate response measure

Douglas S. Brungart[a)]
Air Force Research Laboratory, Human Effectiveness Directorate, Wright-Patterson AFB, Ohio 45433-7901

(Received 20 April 2000; revised 28 June 2000; accepted 23 January 2001)



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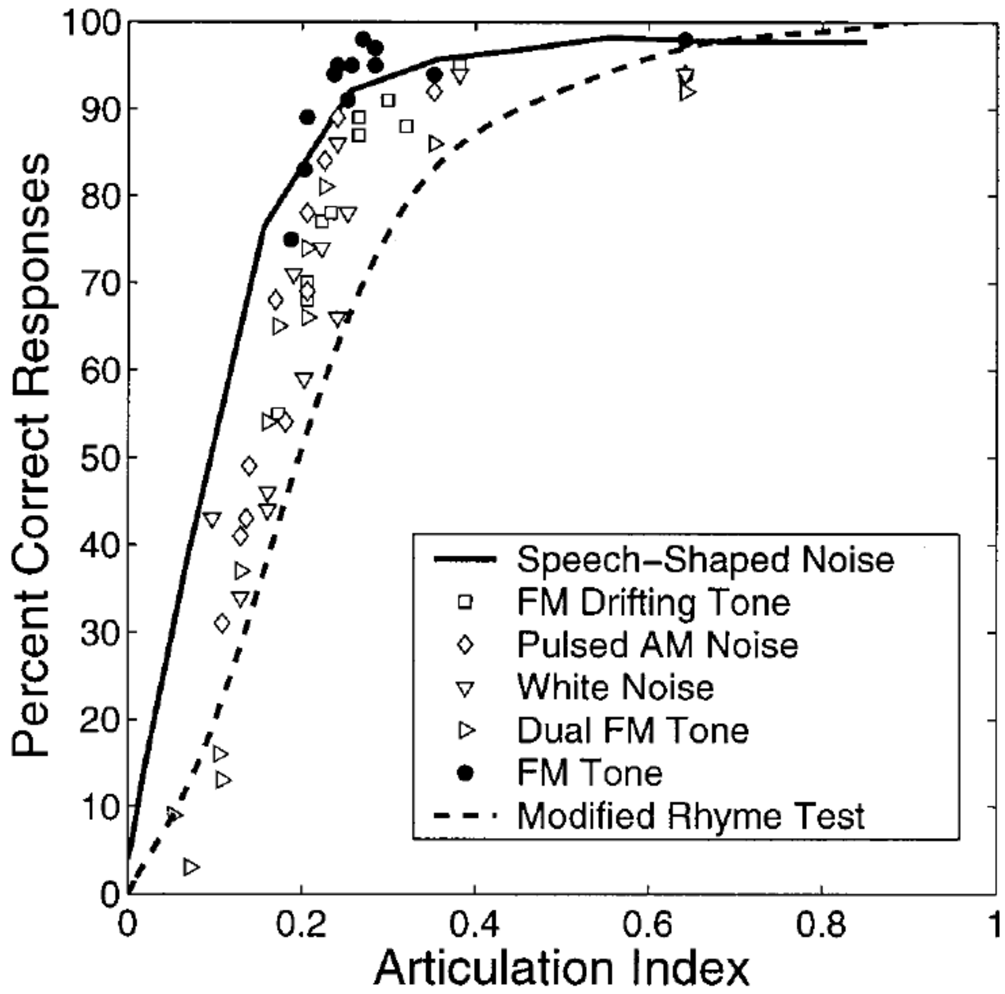

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Independent impacts of age and hearing loss on spatial release in a complex auditory environment

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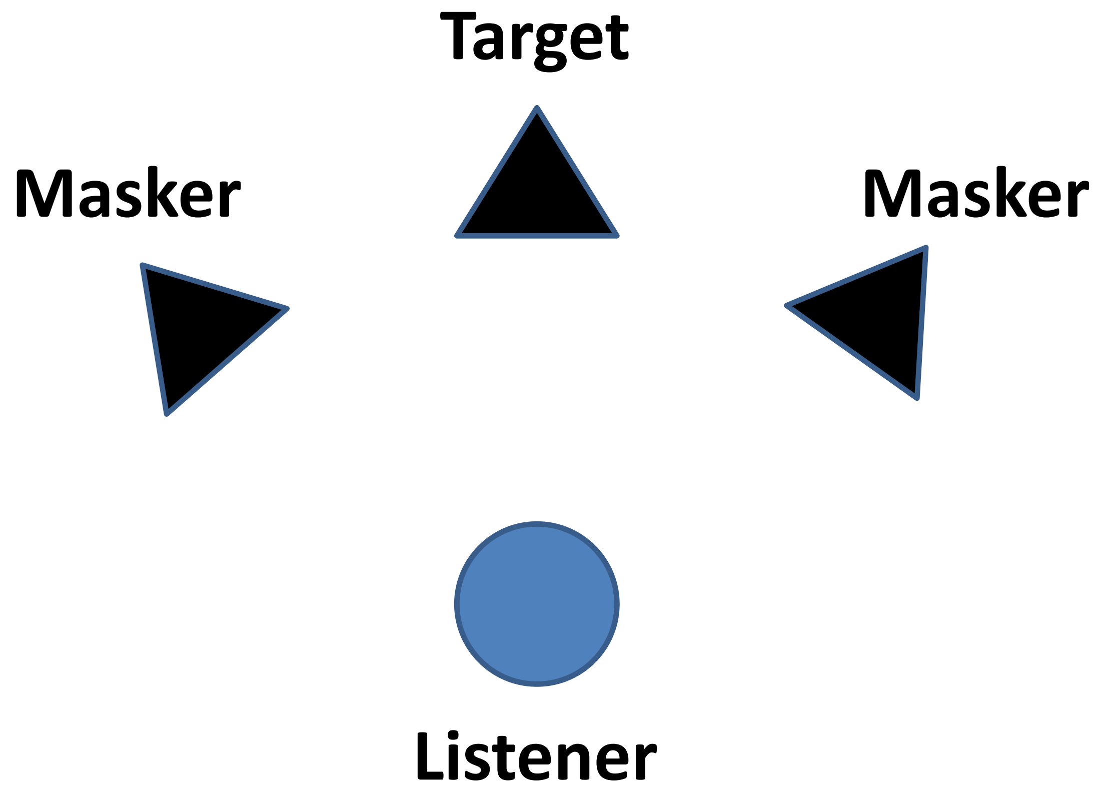
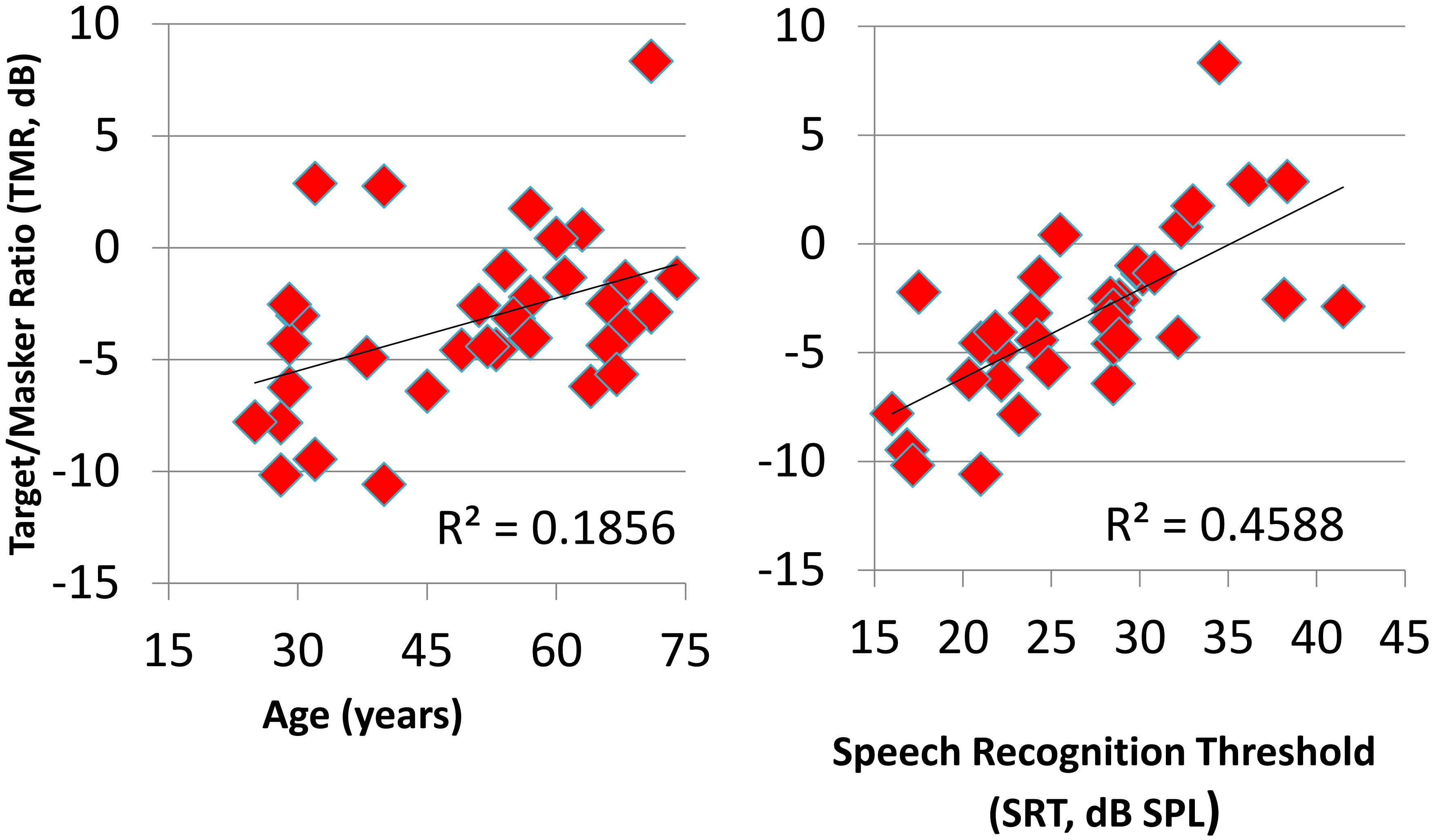
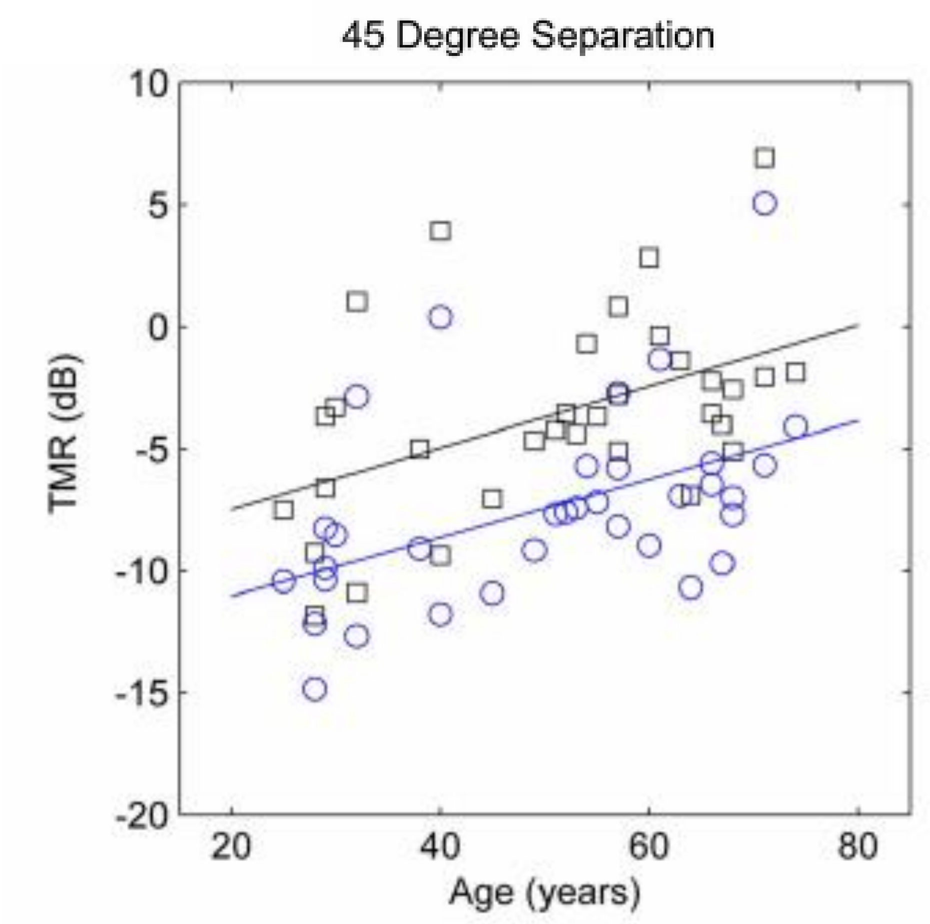


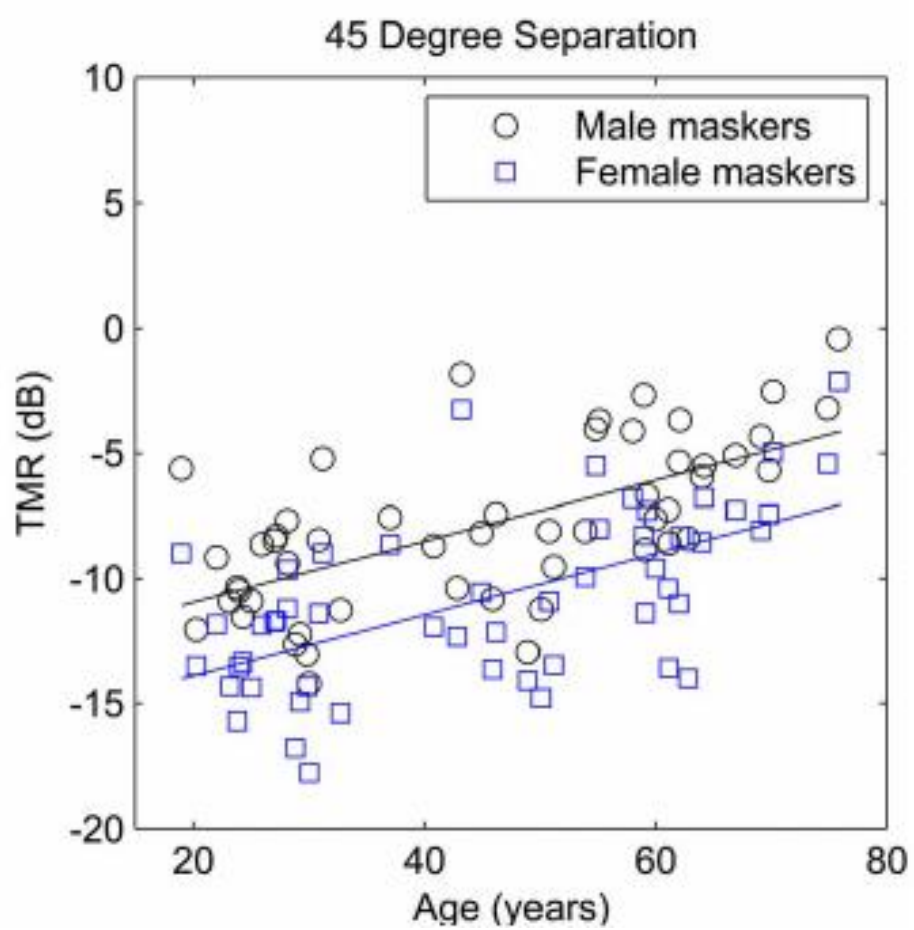
Male Target and Male Maskers Spatially Separated (45 degrees)



Experiment One:
Anechoic Chamber

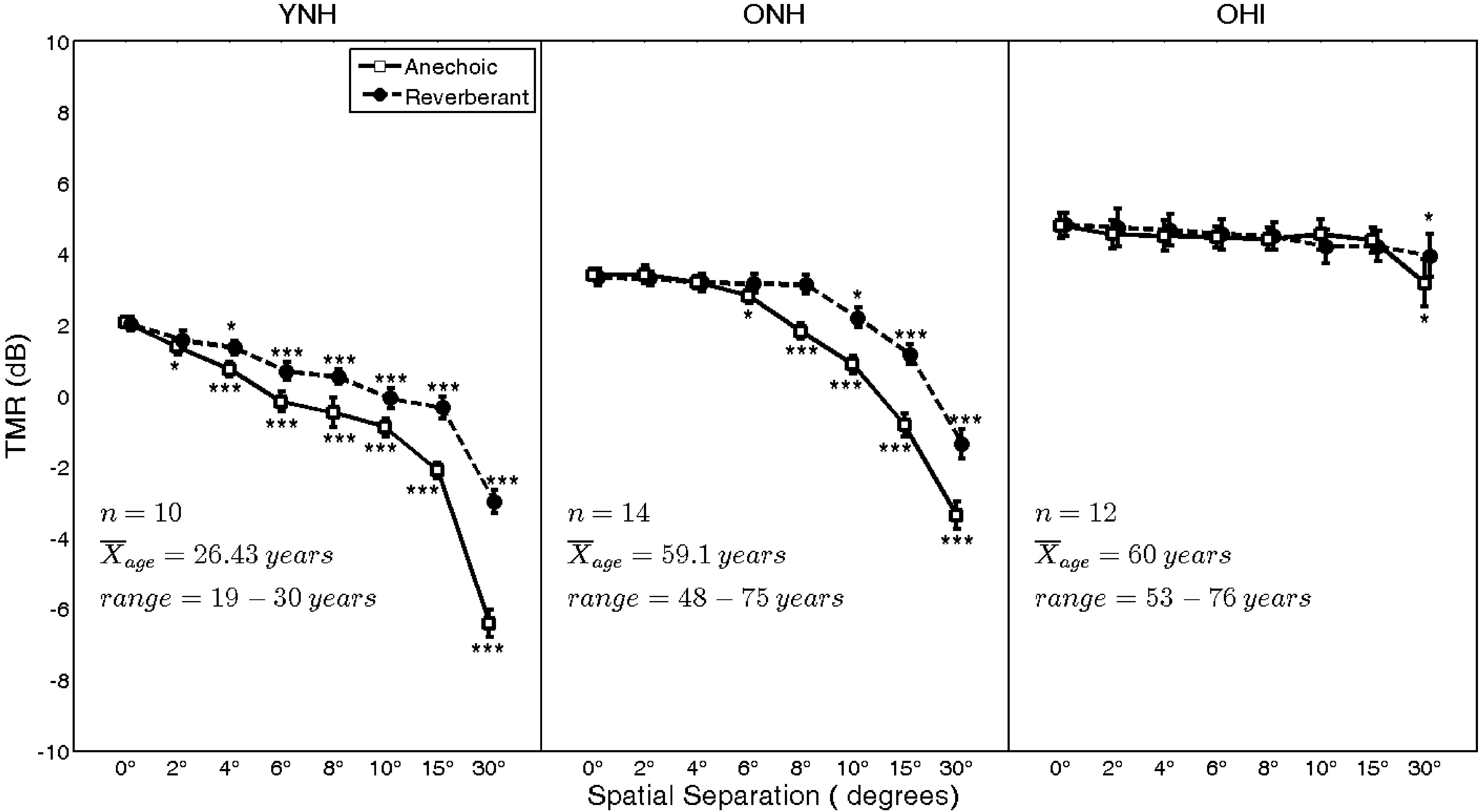


Experiment Two:
Virtual space



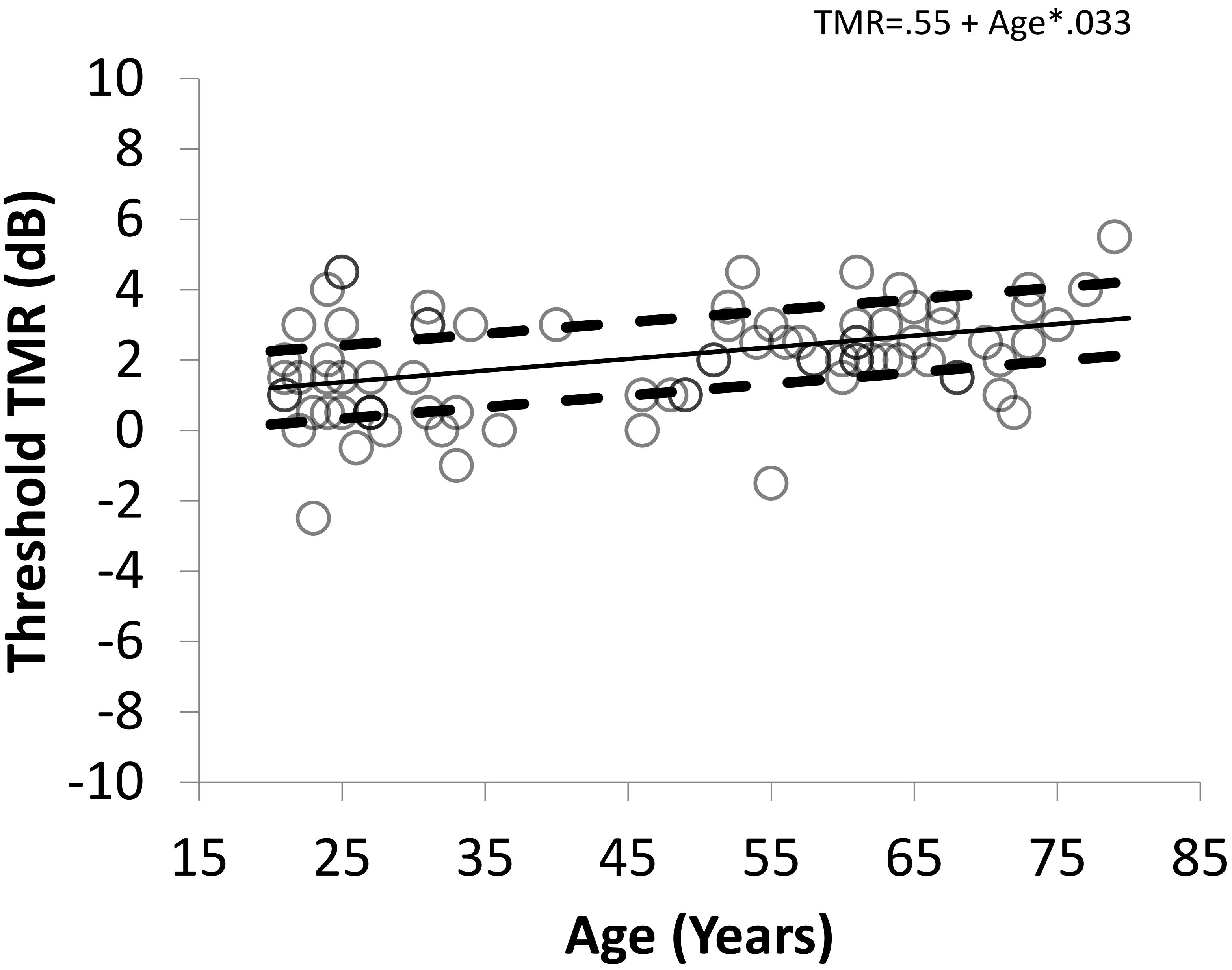
Release from masking for small spatial separations: Effects of age and hearing loss

Srinivasan, Jakien, and Gallun (2016)

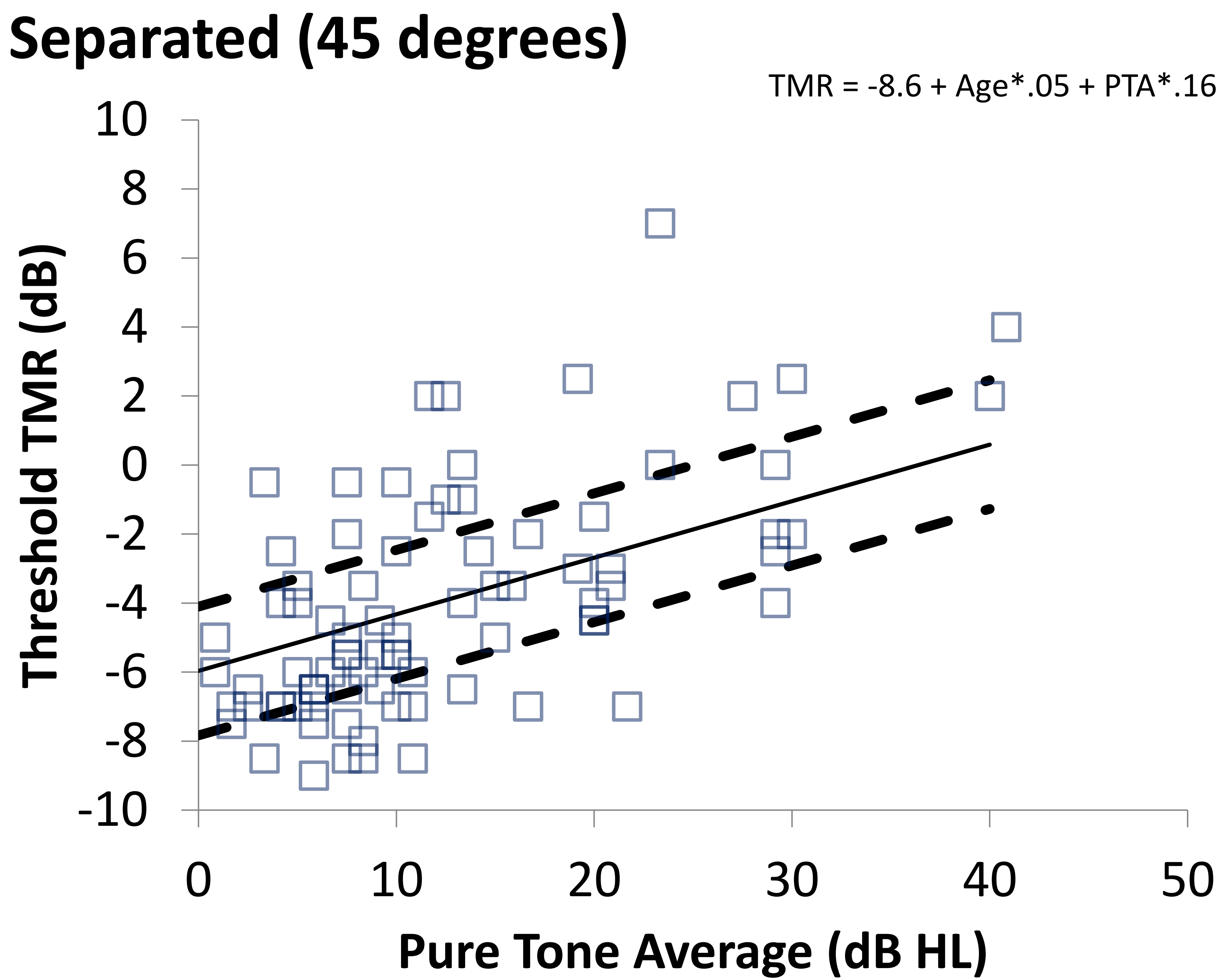


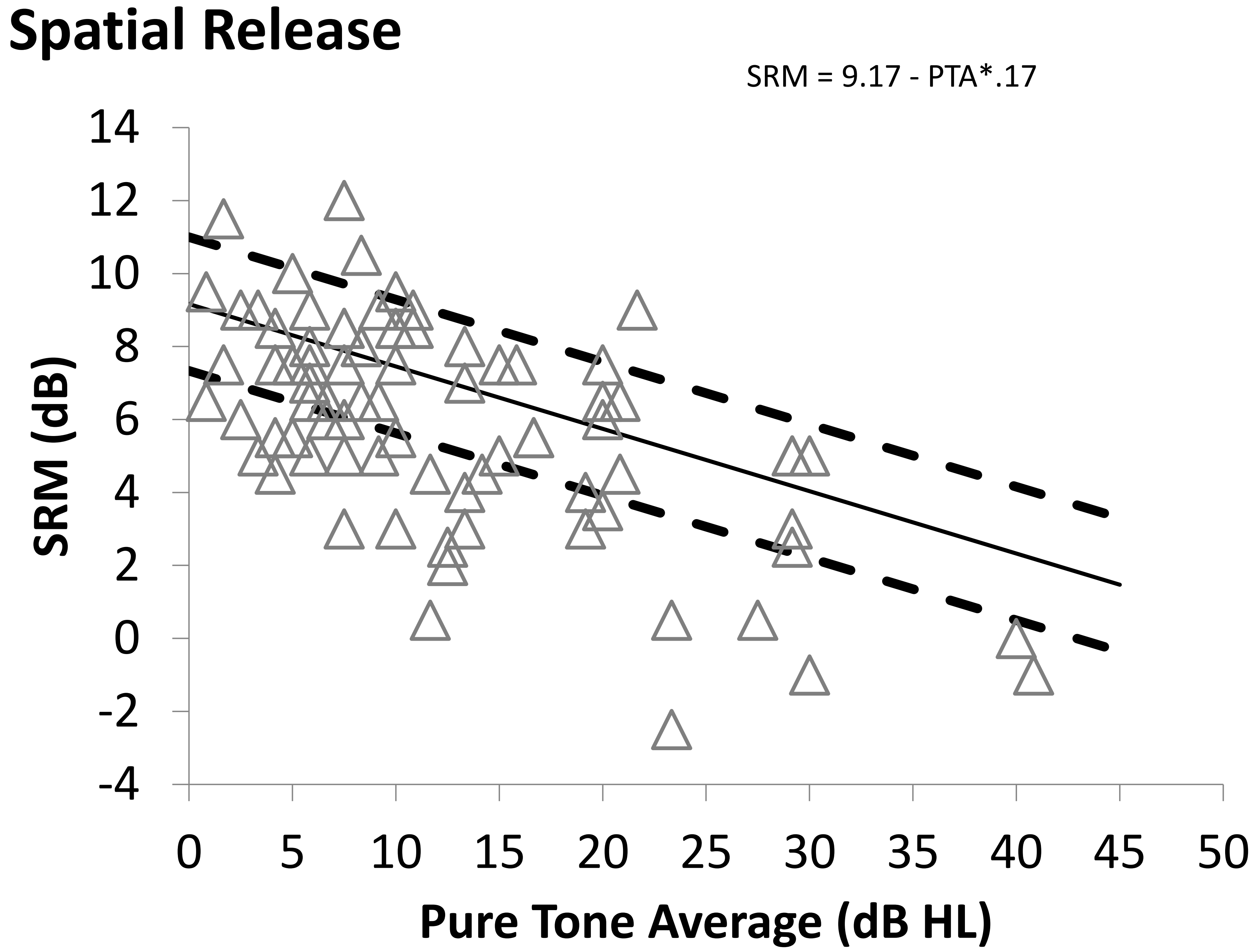
YNH
ONH
OHI
Anechoic
Reverberant
TMR (dB)
Spatial Separation (degrees)
0° 2° 4° 6° 8° 10° 15° 30°
10 8 6 4 2 0 -2 -4 -6 -8 -10
$n = 10$
$\overline{X}_{age} = 26.43\, years$
$range = 19 - 30\, years$
$n = 14$
$\overline{X}_{age} = 59.1\, years$
$range = 48 - 75\, years$
$n = 12$
$\overline{X}_{age} = 60\, years$
$range = 53 - 76\, years$

Colocated



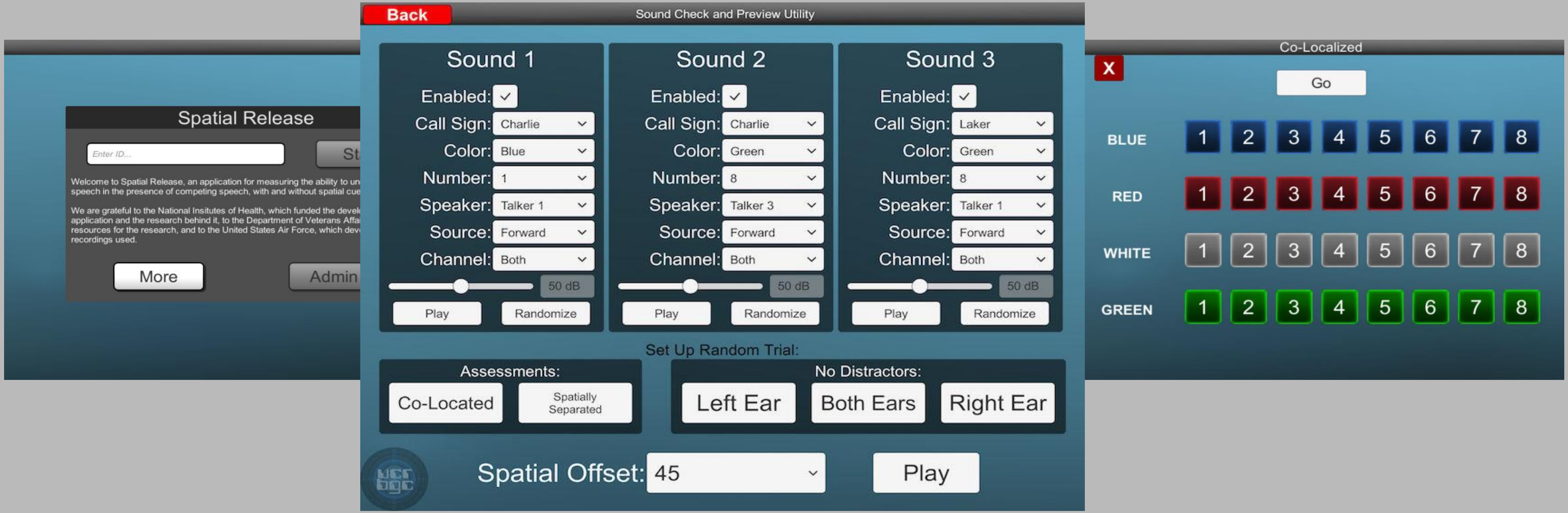
Jakien and Gallun (2018)


Separated (45 degrees)
TMR = -8.6 + Age*.05 + PTA*.16
Threshold TMR (dB)
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
10
20
30
40
50
Pure Tone Average (dB HL)



Spatial Release
SRM = 9.17 - PTA*.17
SRM (dB)
14
12
10
8
6
4
2
0
-2
-4
0
5
10
15
20
25
30
35
40
45
50
Pure Tone Average (dB HL)

The app “Spatial Release” is a stand-alone version of the spatial release tests that are now included in PART as well.



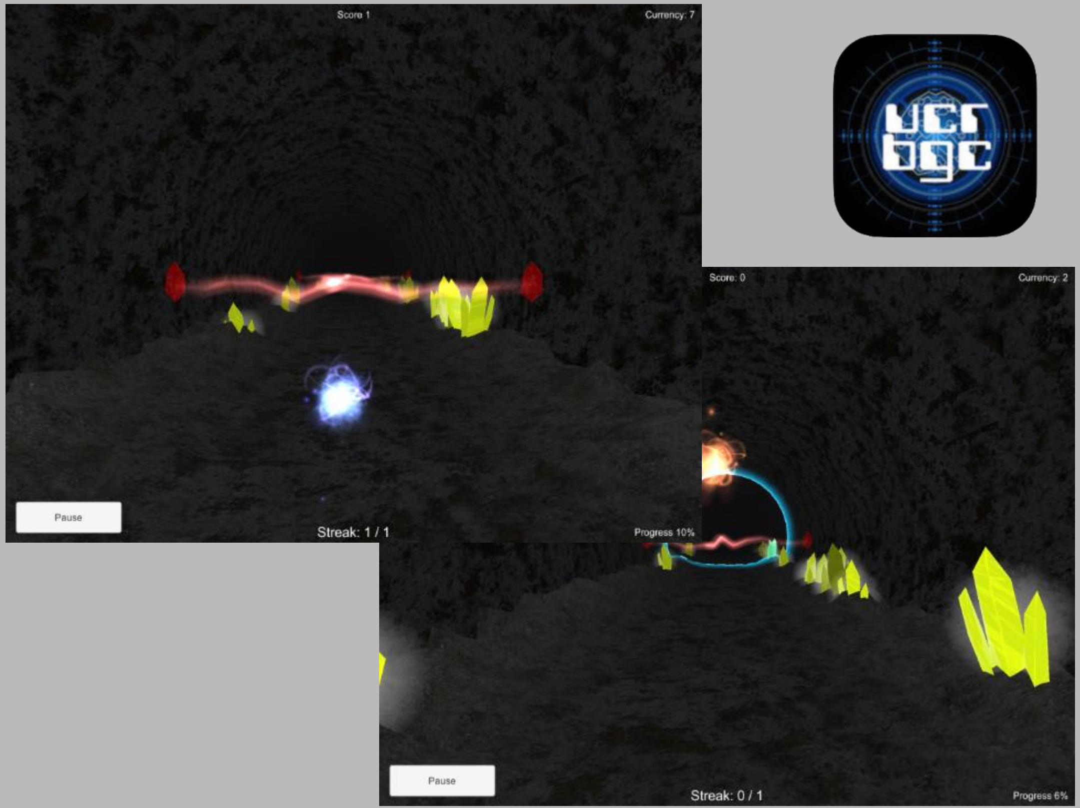
PART 6

What Can Be Done?

The Promise of Auditory Brain Training

We are actively pursuing the possibility that performance can be improved through auditory training, using portable, tablet-based video games.

This approach has been successful with vision training, and we are in the process of developing games that can be used to train temporal, spectral, and spatial auditory abilities as well.



"Listen: An Auditory Training Experience" combines an engaging auditory game experience with training in spectrotemporal modulation sensitivity and spatial awareness, and is available on the iTunes store.

https://bgc.ucr.edu/games

Thank you for your attention!