Hidden Hearing Loss

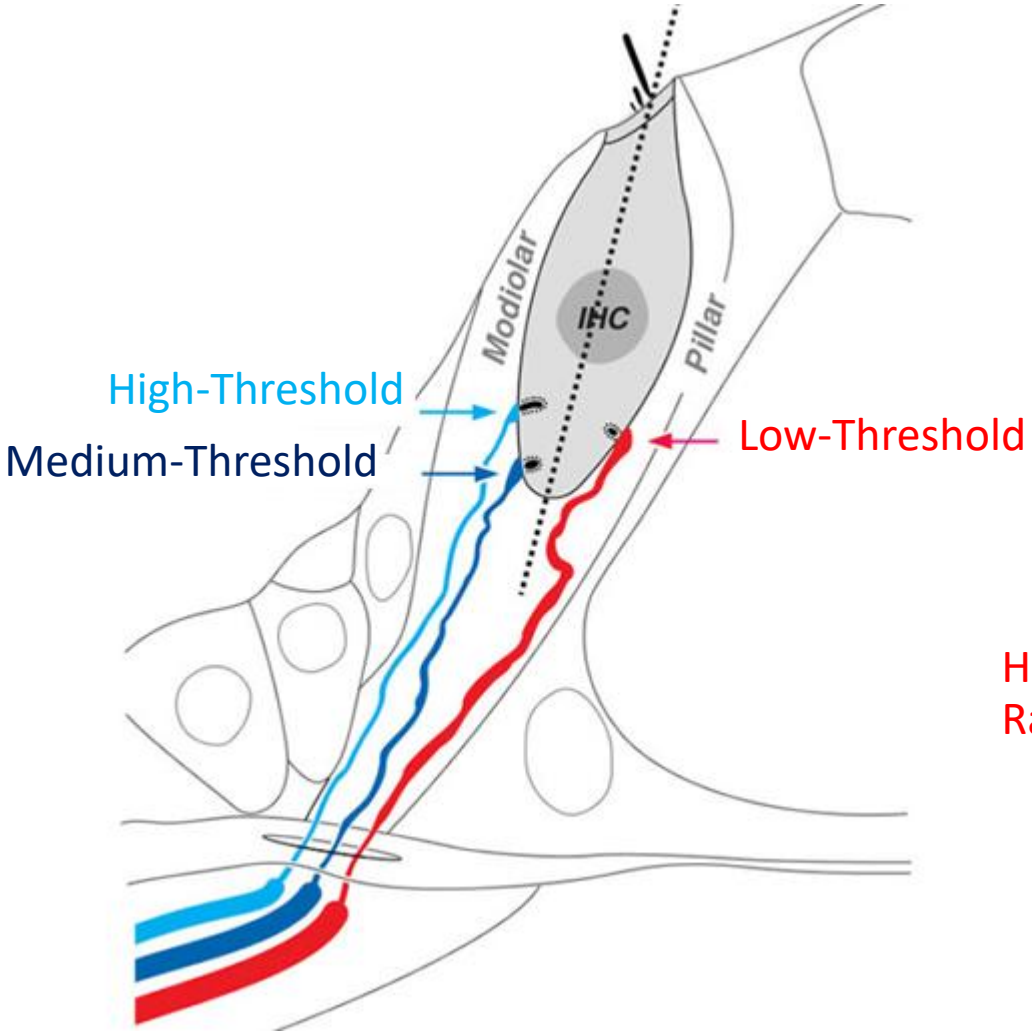
Dr. Joaquin Valderrama (joaquin.valderrama@nal.gov.au)

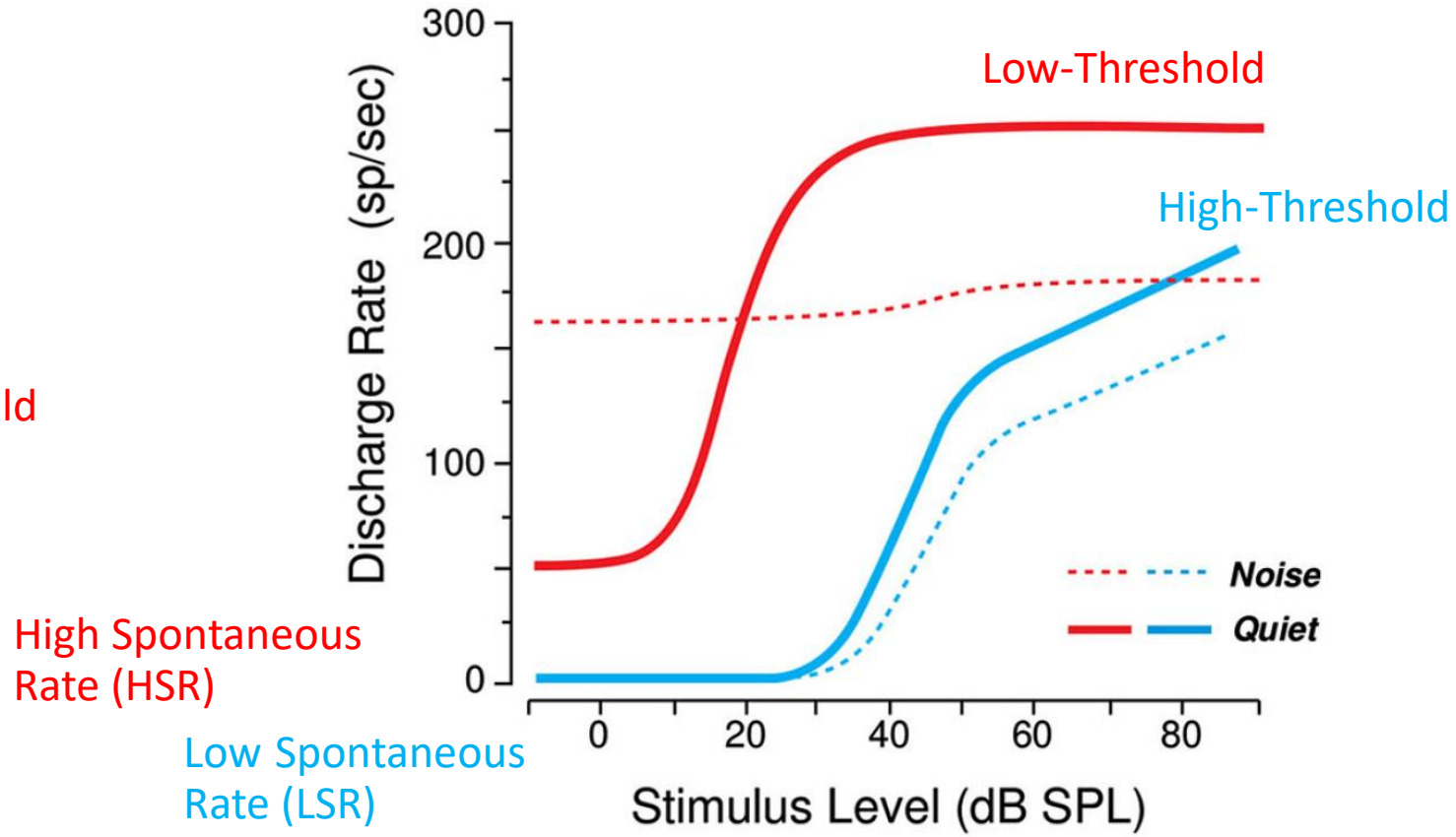
National Acoustic Laboratories

Dpt of Linguistics, Macquarie University

Sydney, 30th of September, 2019

- 120 dB → $I_{max} = 1{,}000{,}000{,}000{,}000 \cdot I_{min}$





High Spontaneous Rate (HSR)

Low Spontaneous Rate (LSR)

HT fibres (LSRs) play an important role in speech perception in noise

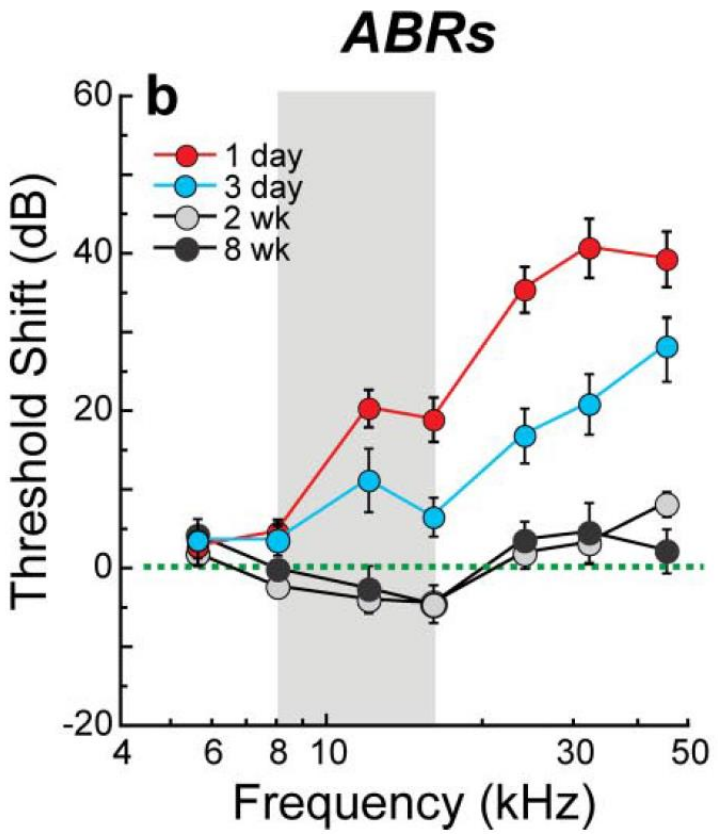
Behavioral/Systems/Cognitive

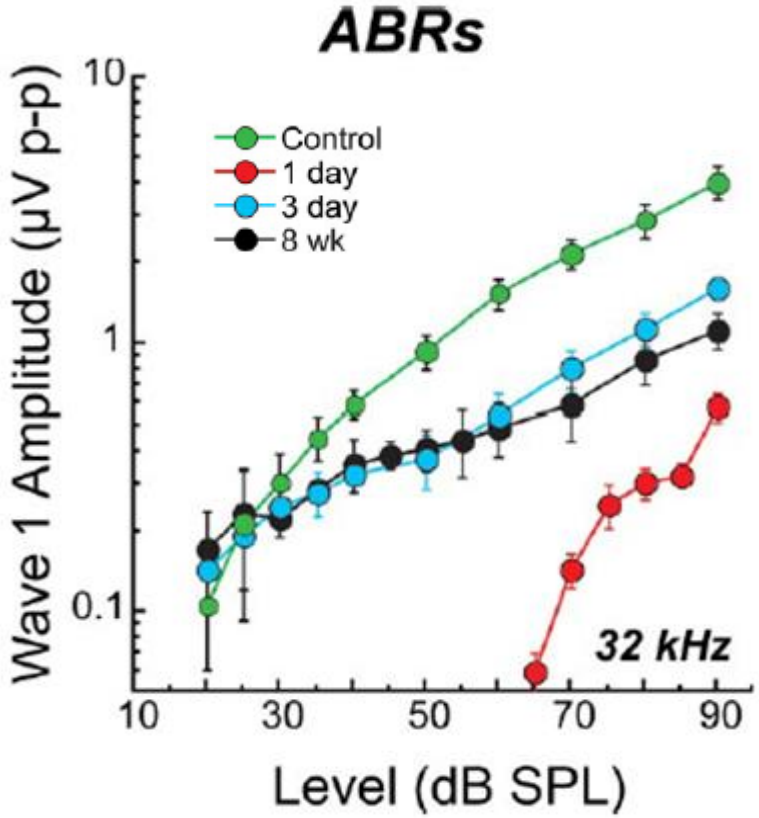
The Journal of Neuroscience, November 11, 2009 • 29(45):14077–14085 • 14077

Adding Insult to Injury: Cochlear Nerve Degeneration after "Temporary" Noise-Induced Hearing Loss

Sharon G. Kujawa[1,2,3,4] and M. Charles Liberman[1,2,4]

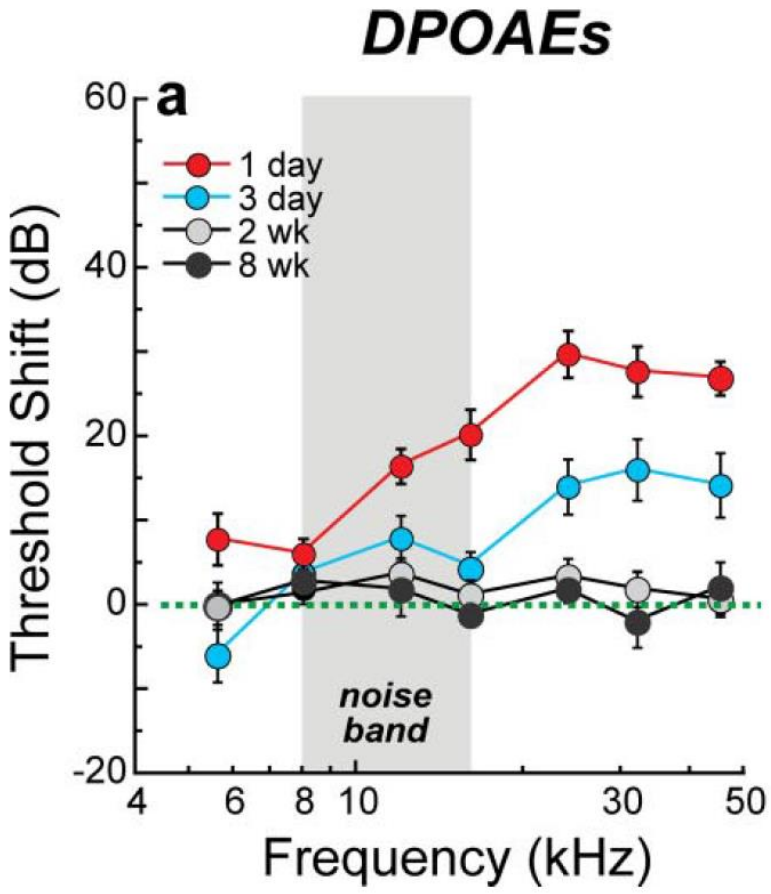
- Anaesthetized mice
- 8-16 kHz noise
- 2 h, 100 dB SPL

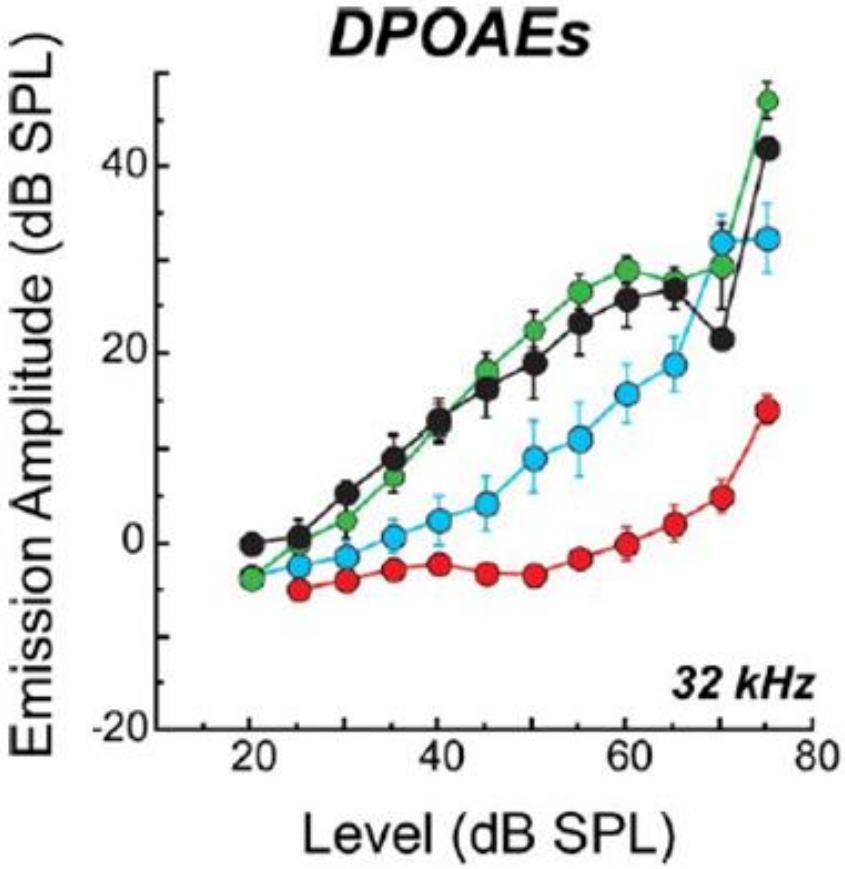




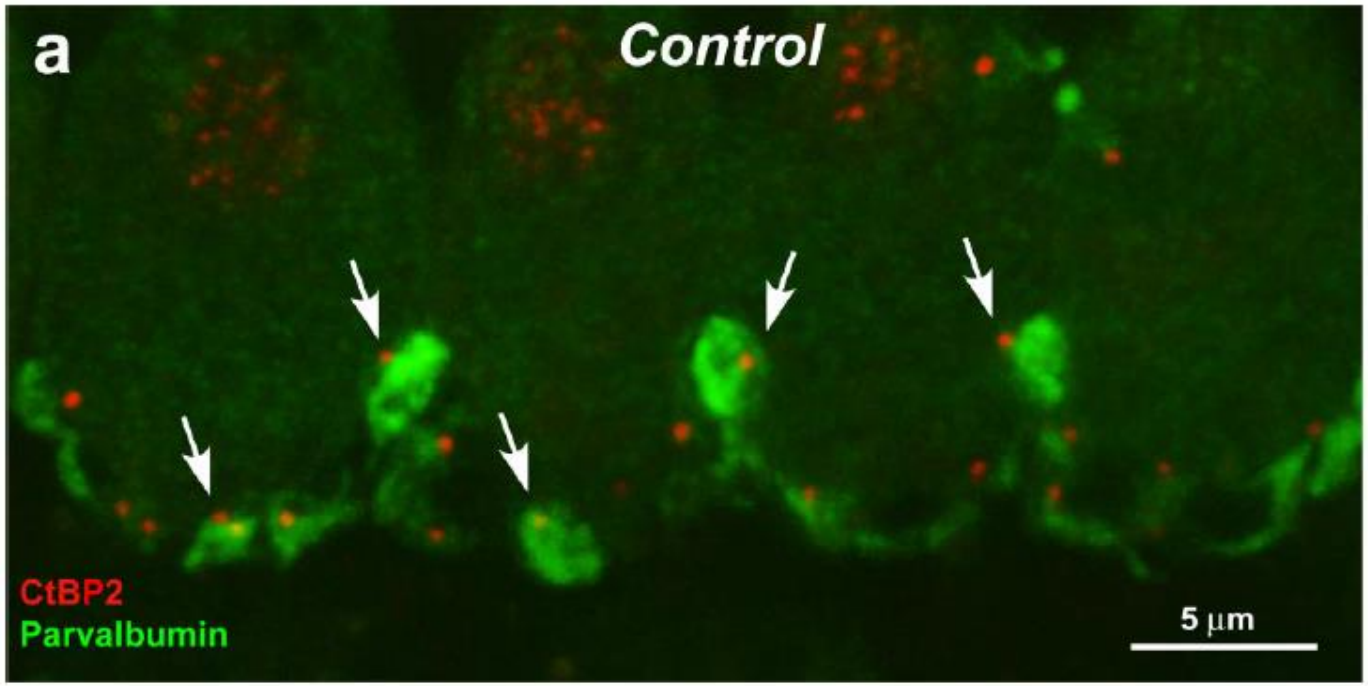
Noise damaged HT fibers

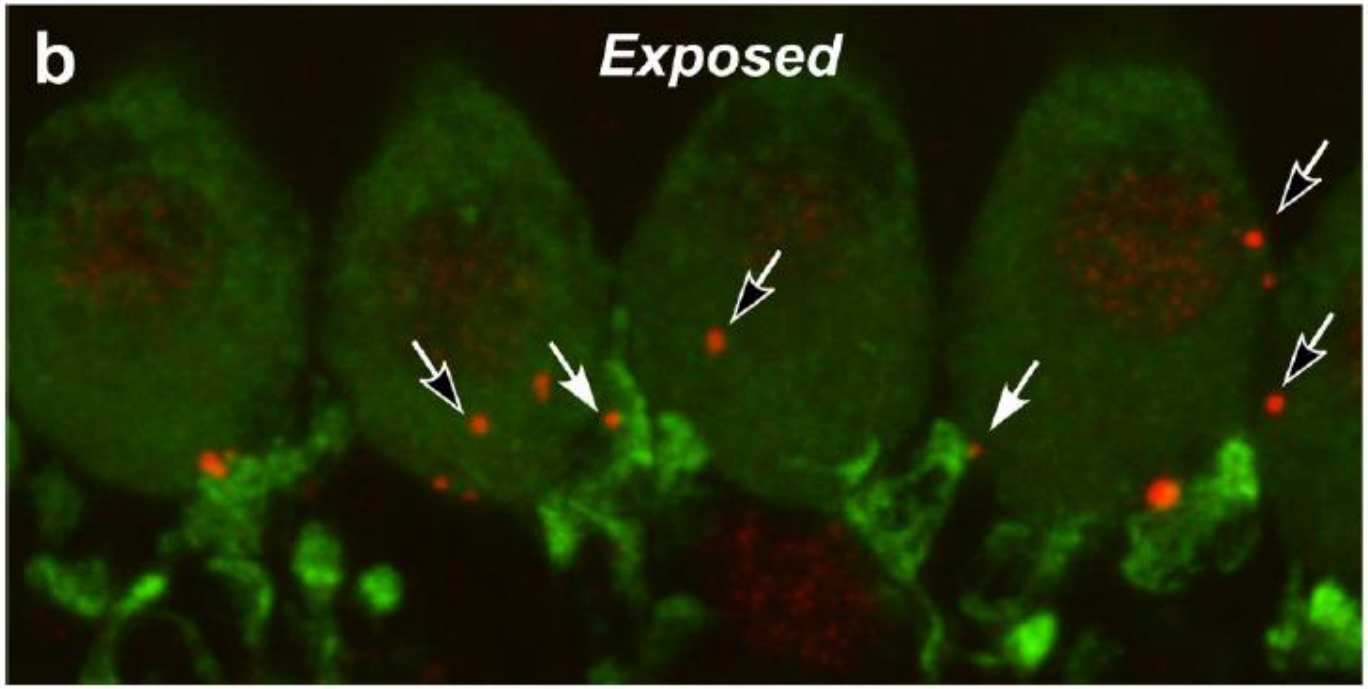
And how were hair cells affected?

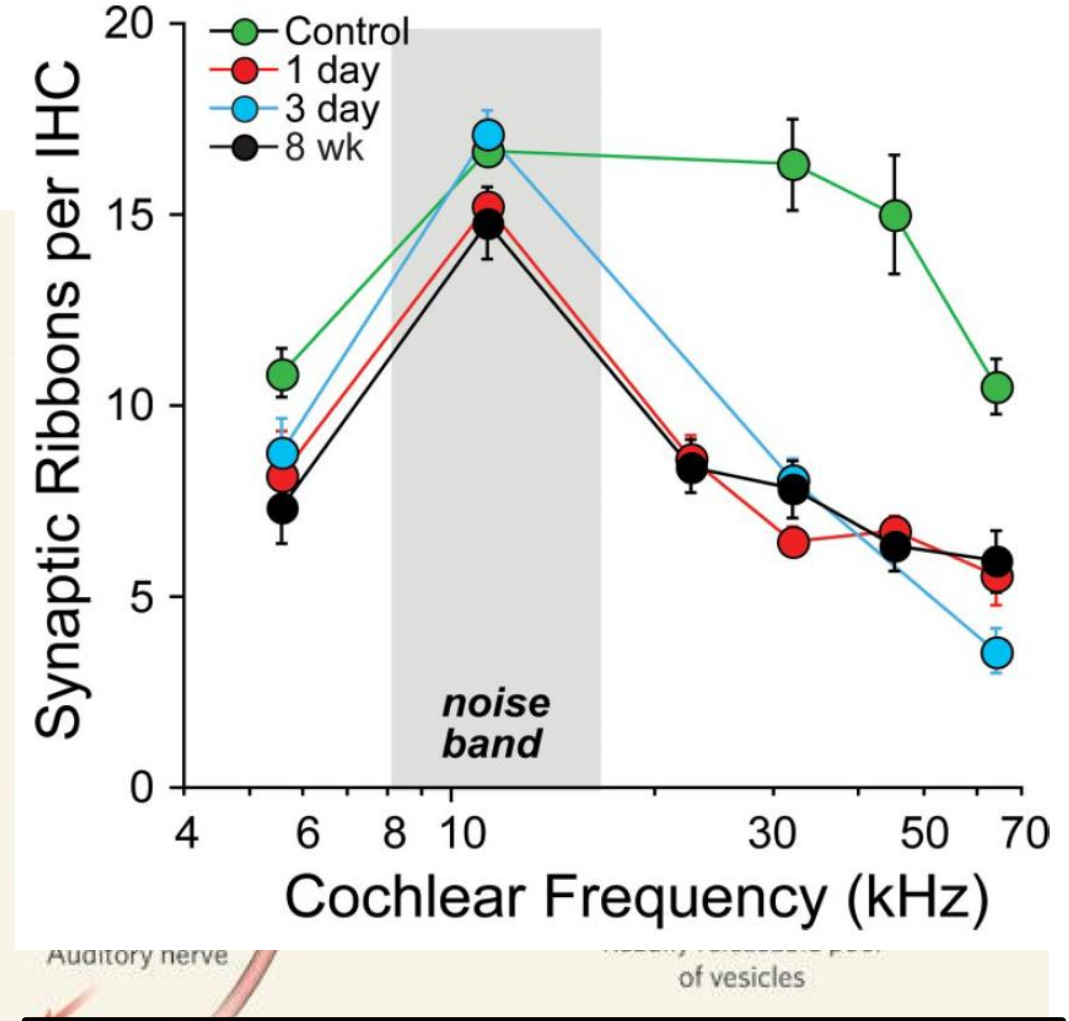




Noise did not damage outer hair cells





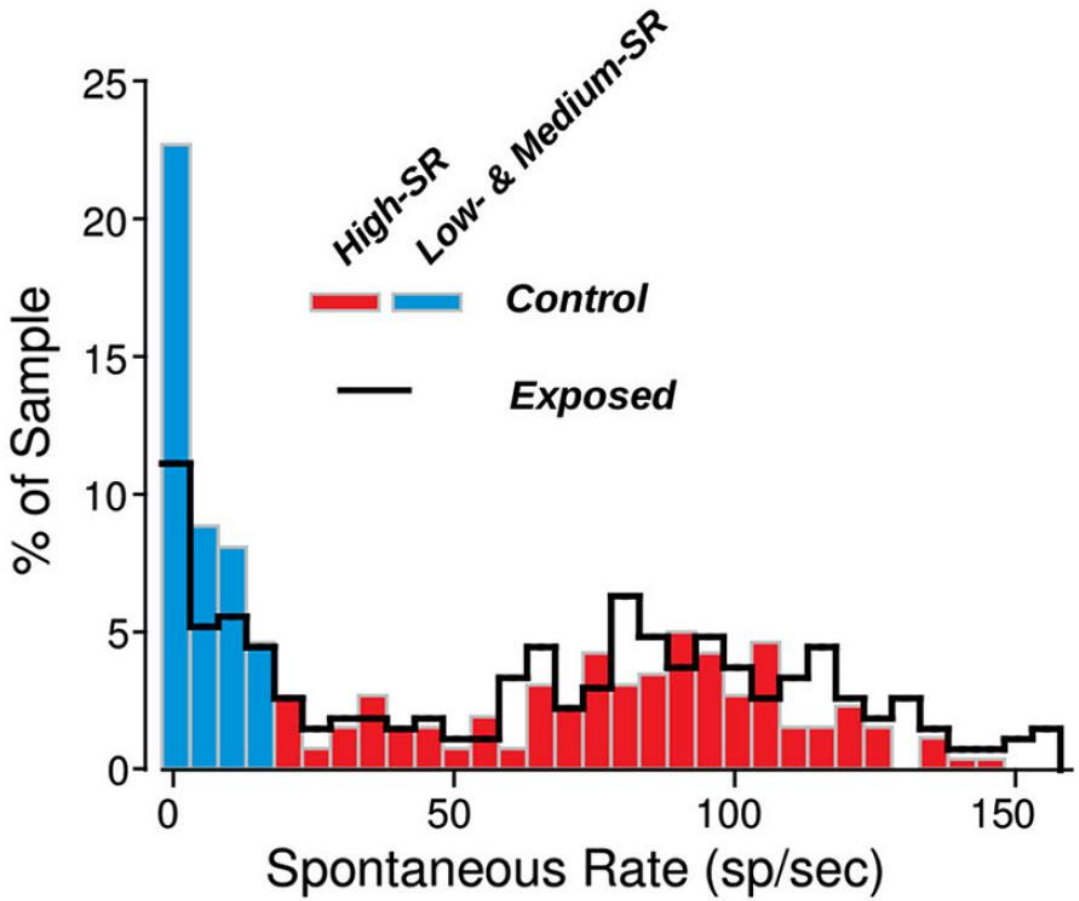


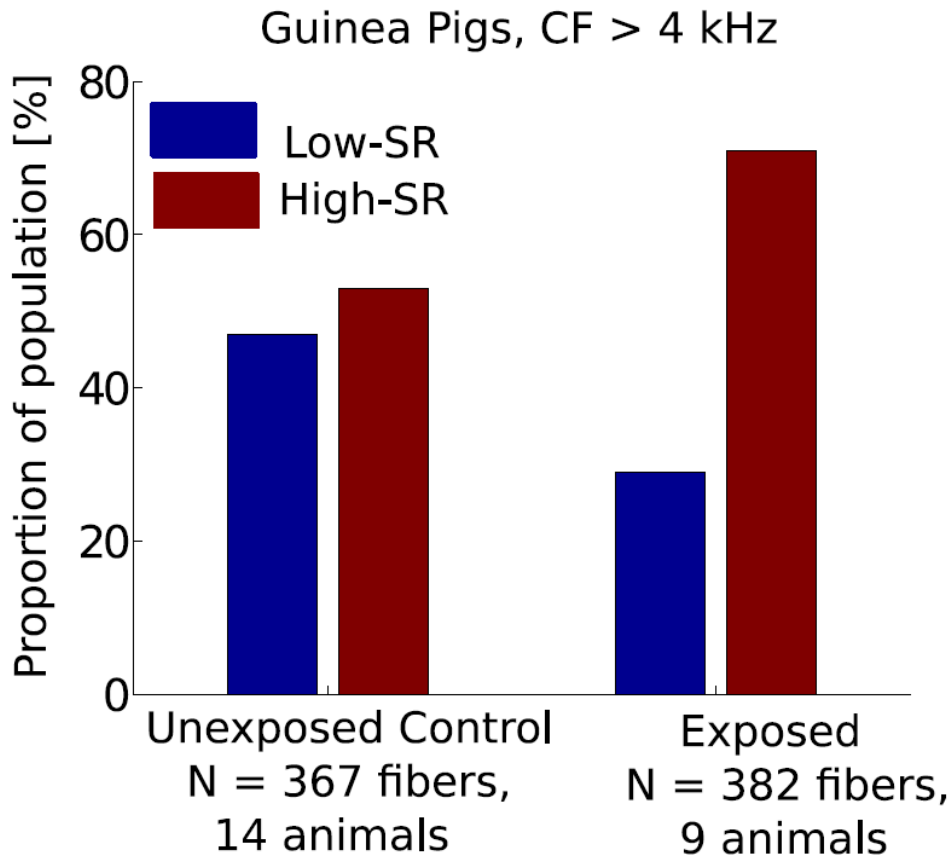
Noise-exposure “disconnects” hair cell synaptic ribbons from cochlear nerve terminals

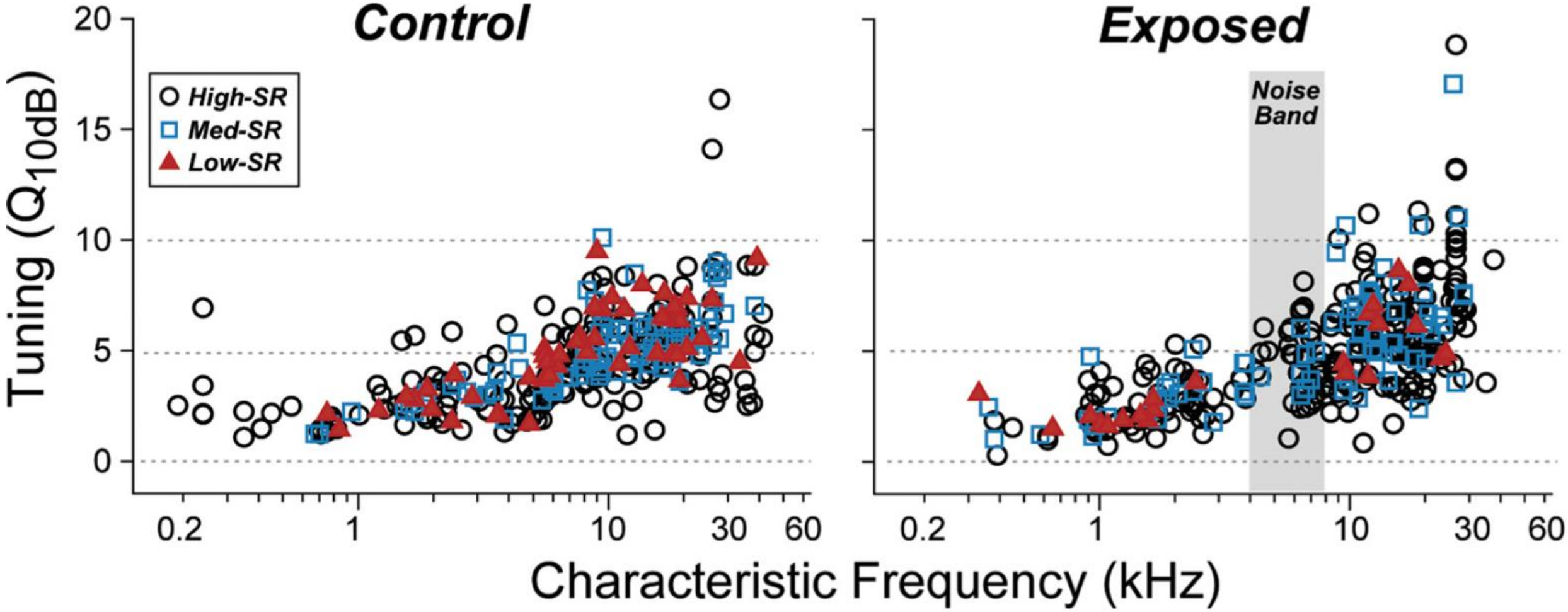
J Neurophysiol 110: 577–586, 2013.
First published April 17, 2013; doi:10.1152/jn.00164.2013.

Noise-induced cochlear neuropathy is selective for fibers with low spontaneous rates

Adam C. Furman,[2,4] Sharon G. Kujawa,[1,3,4] and M. Charles Liberman[1,2,4]





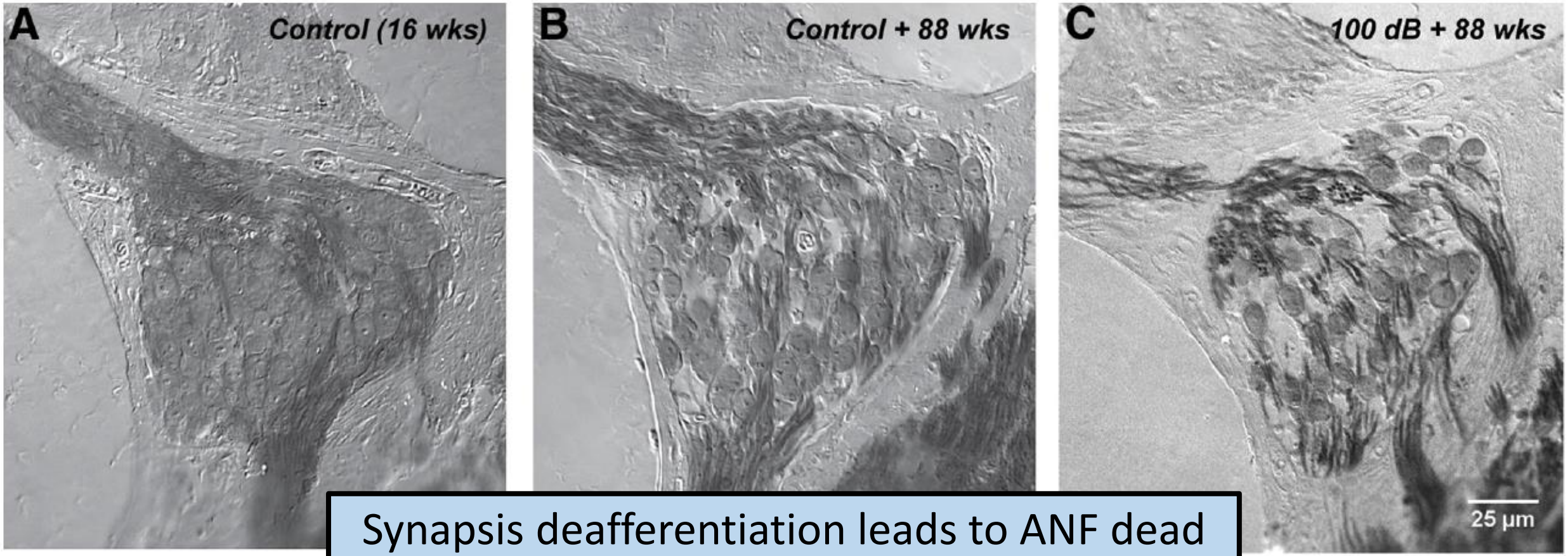


Noise exposure affects HT-ANF

The Journal of Neuroscience, May 13, 2015 • 35(19):7509–7520 • 7509

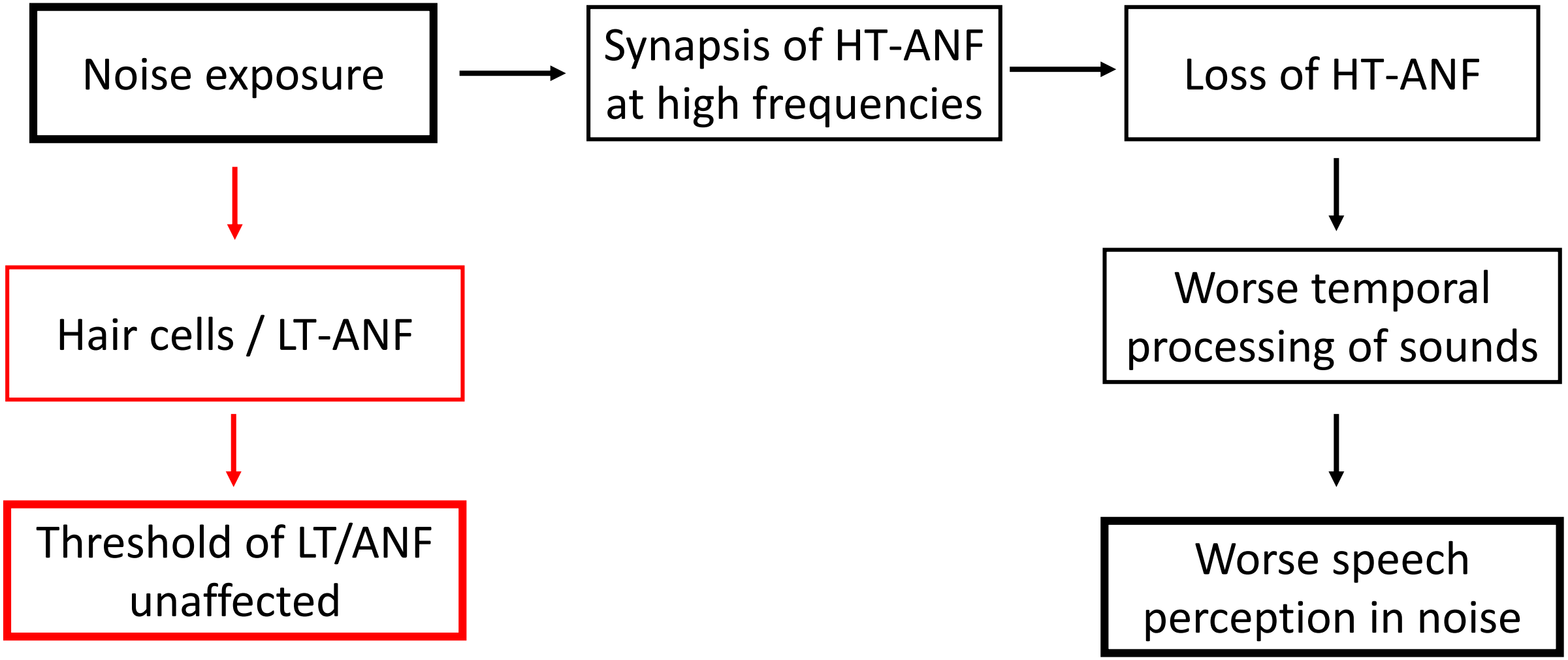
Aging after Noise Exposure: Acceleration of Cochlear Synaptopathy in "Recovered" Ears

Katharine A. Fernandez,[1,2] Penelope W.C. Jeffers,[2] Kumud Lall,[1,2] M. Charles Liberman,[1,2] and Sharon G. Kujawa[1,2,3]



Synapsis deafferentiation leads to ANF dead

Animal model of Hidden Hearing Loss



Quiz

- What neurons participate mostly in understanding speech in noise?
  - High-Threshold / Low-Spontaneous Rate Auditory Nerve Fibers
- Who were the authors of a very relevant study that has influenced HHL research?
  - Sharon Kujawa & Charles Liberman
- In what year?
  - 2009
- According to this study, what happened to thresholds after noise exposure?
  - They recovered
- Does this mean that noise exposure is harmless?
  - No, it affects HT-ANF
- What is the consequence of losing HT-ANF?
  - Worse temporal processing of sounds, thus worse speech perception in noise

References

- Kujawa SG, Liberman MC (**2009**). “Adding insult to injury: cochlear nerve degeneration after ‘temporary’ noise-induced hearing loss”. The Journal of Neuroscience 29(45): 14077-14085.
- Furman AC, Kujawa SG, Liberman MC (**2013**). “Noise-induced cochlear neuropathy is selective for fibers with low spontaneous rates”. Journal of Neurophysiology 110: 577-586.
- Fernandez KA, Jeffers PWC, Lall K, Liberman MC, Kujawa SG (**2014**). “Aging after noise exposure: acceleration of cochlear synaptopathy in ‘recovered’ ears”. The Journal of Neuroscience 35(19): 7509-7520.
- Bharadwaj HM, Verhulst S, Shaheen L, Liberman MC, Shinn-Cunningham BGS (**2014**). “Cochlear neuropathy and the coding of supra-threshold sound”. Frontiers in Neuroscience 8, article 26.
- Plack CJ, Barker D, Prendergast G (**2014**). “Perceptual consequences of ‘hidden’ hearing loss”. Trends in Hearing 18: 1-11.

Diagnosing HHL in humans

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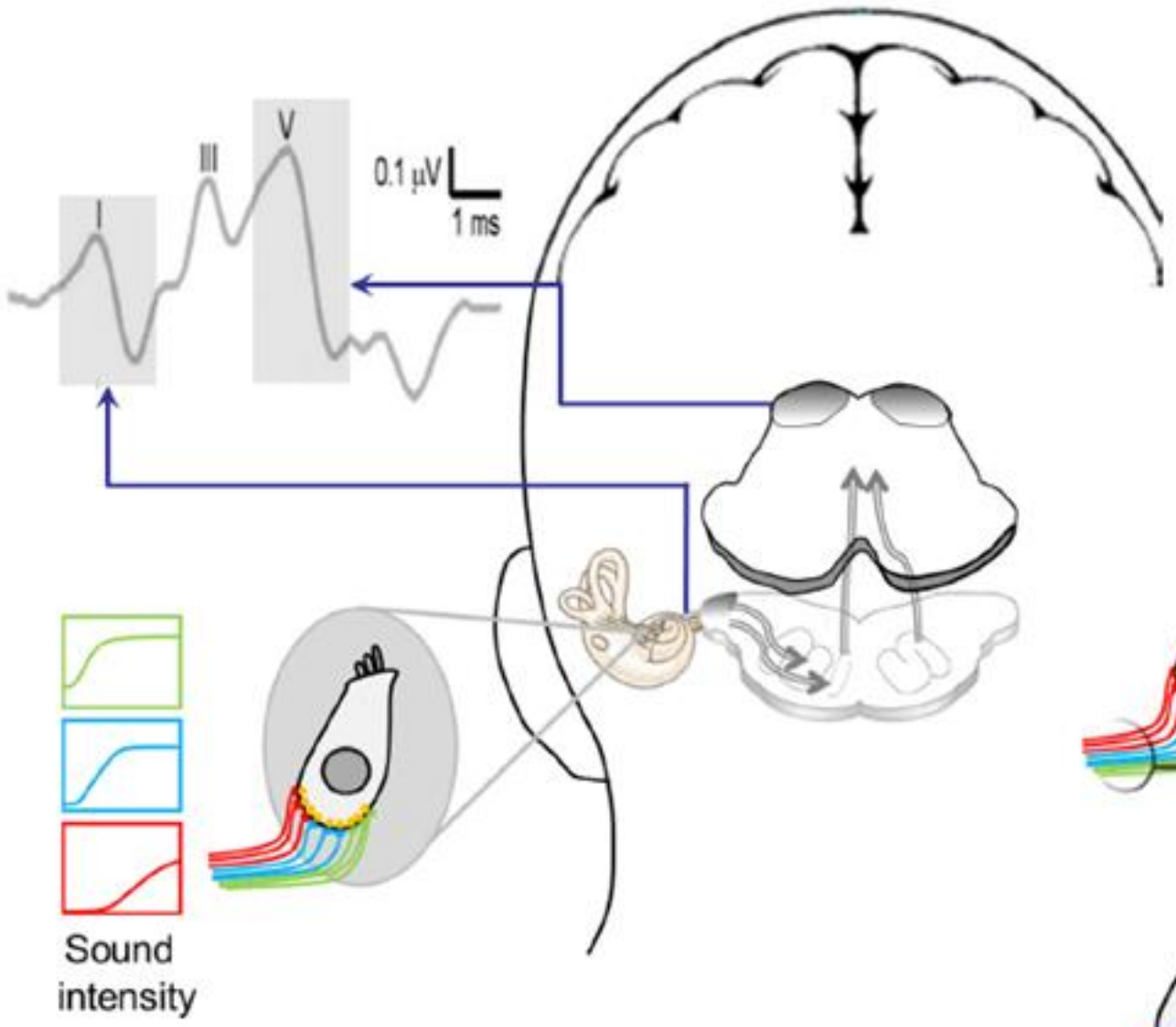
Sydney, 30th of November, 2019

- **Why is it important?**
  - ✓ Audiologists
  - ✓ Society
  - ✓ Industry

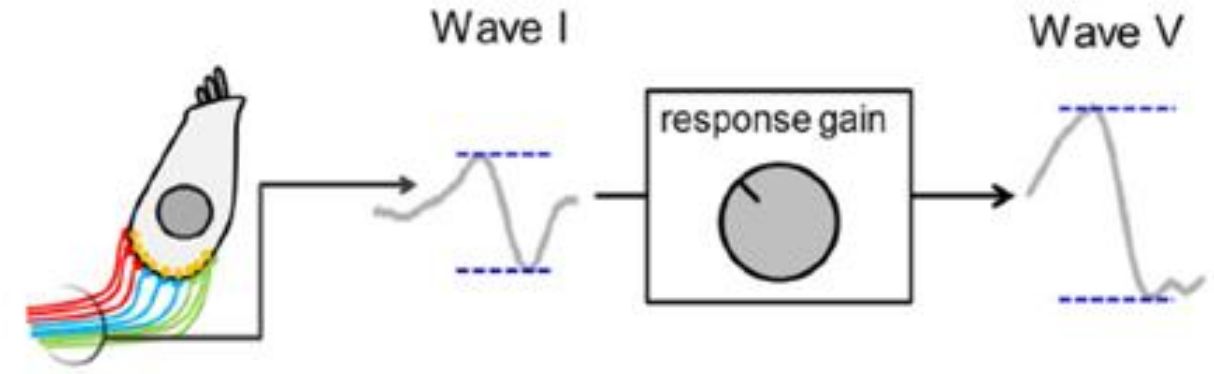
- **What are the main indicators?**
  - ✓ Auditory Brainstem Responses (ABR)
  - ✓ Envelope Following Responses (EFR)

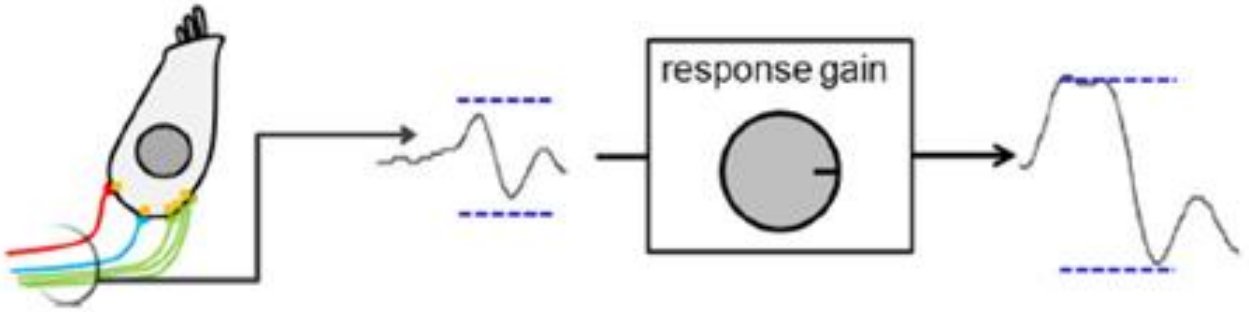
- **What are the obstacles?**
  - ✓ Intersubject variability
  - ✓ Lack of validation

Auditory Brainstem Responses (ABR) – Hypotheses

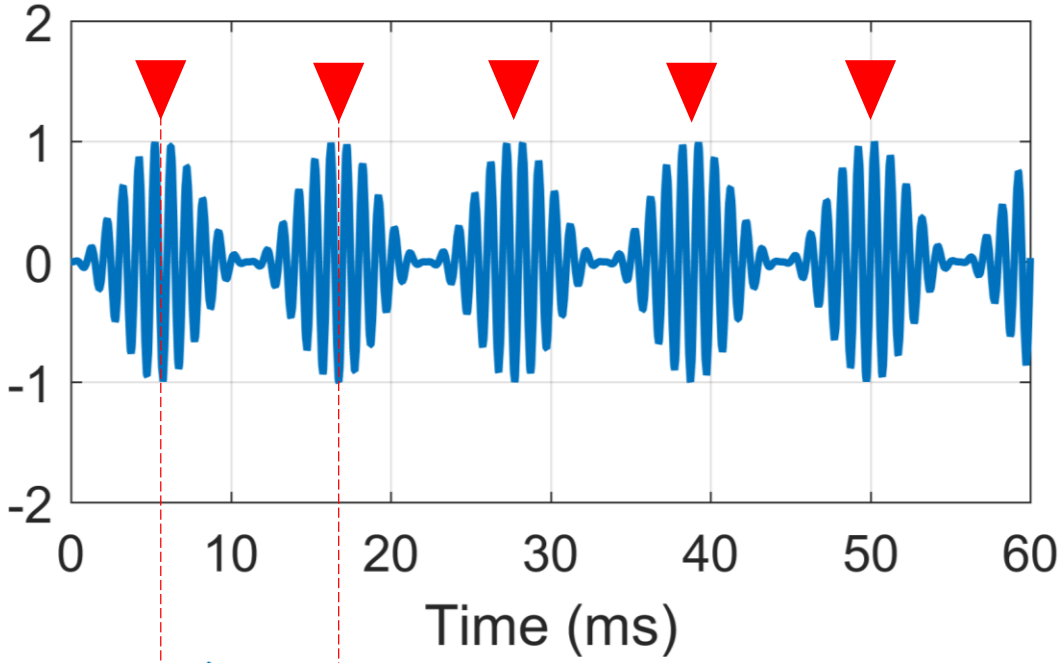


Central gain activation as indicator of cochlear neuropathy

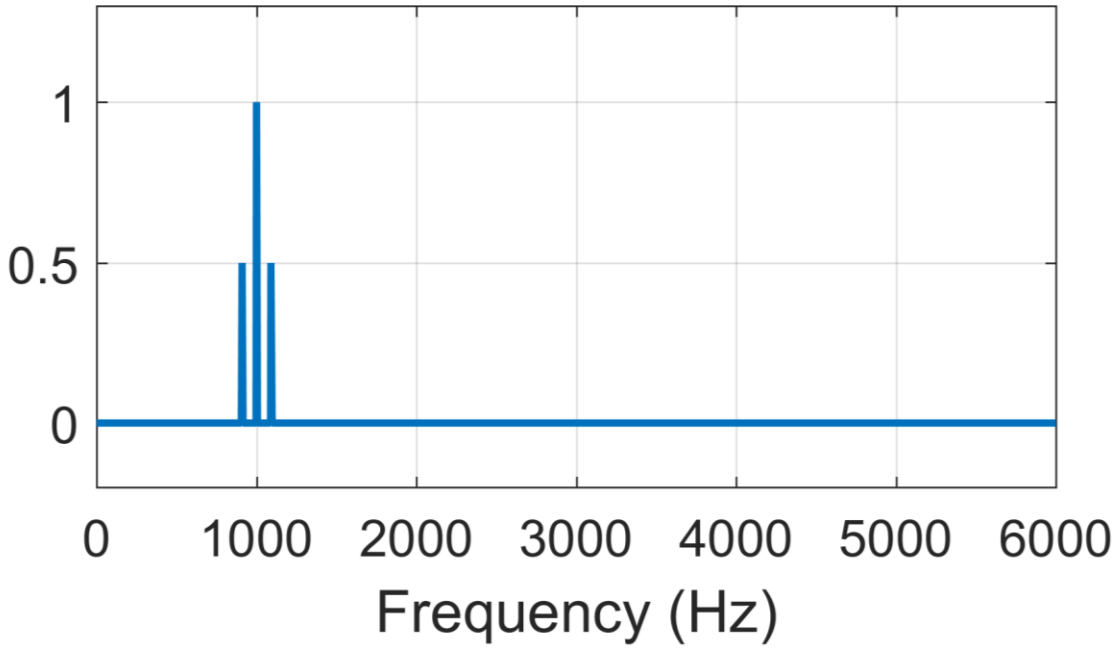


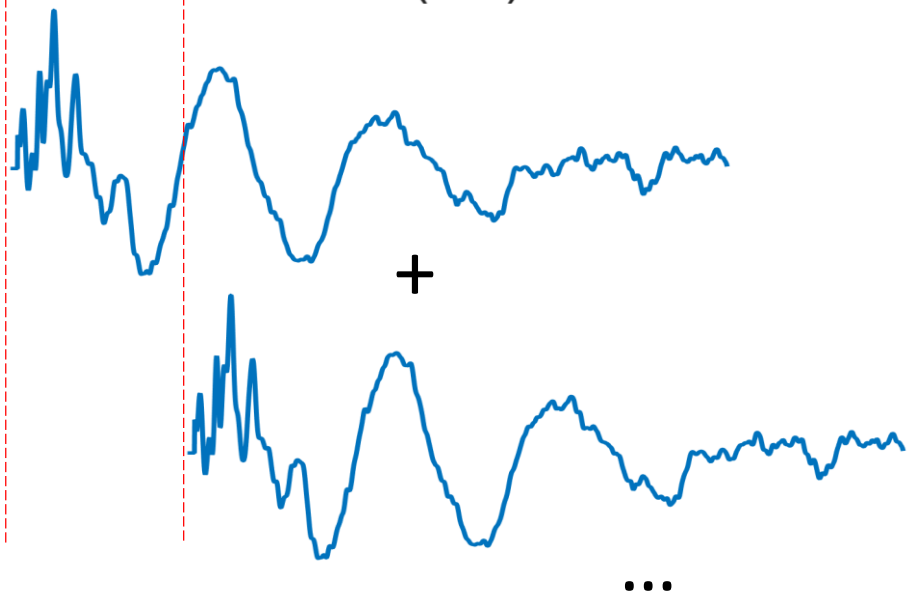


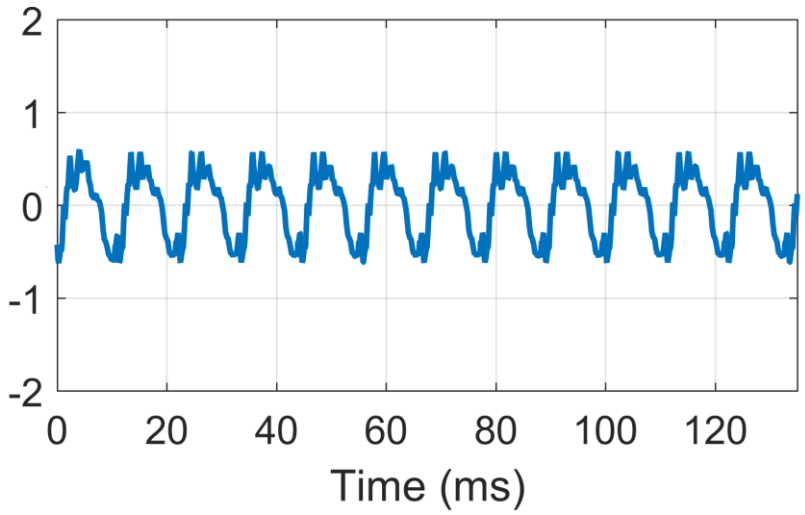
Envelope Following Responses (EFR) – Test

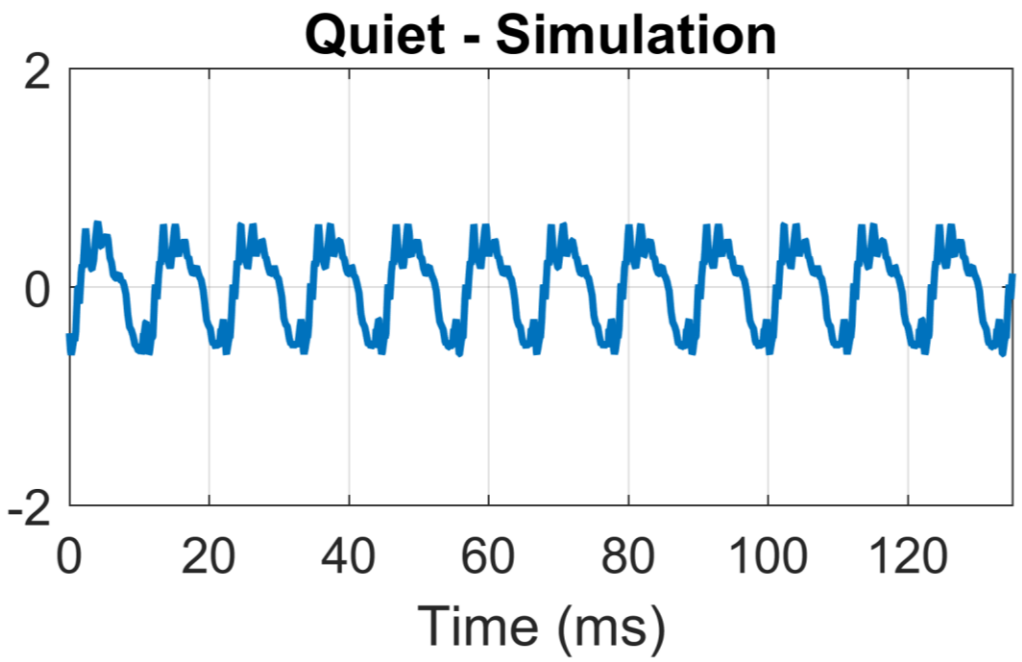


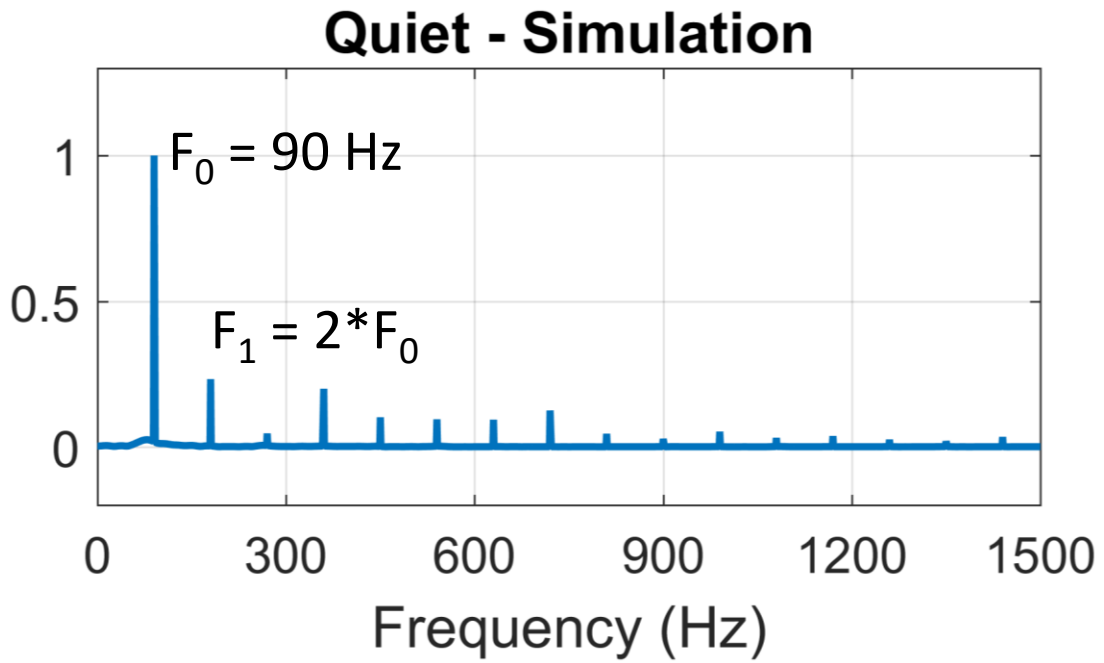
FFT

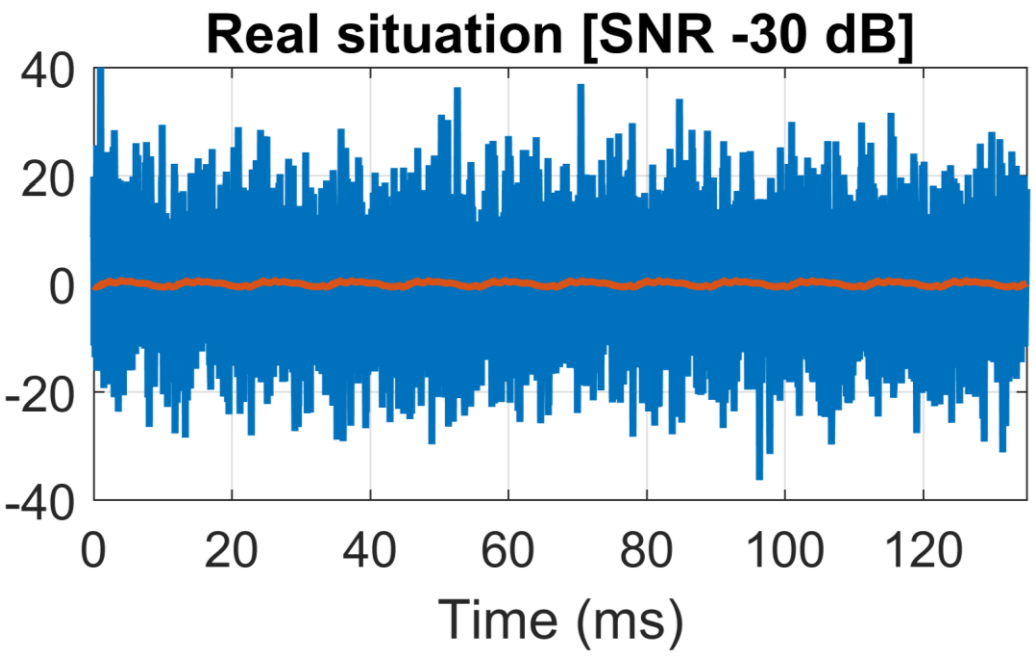


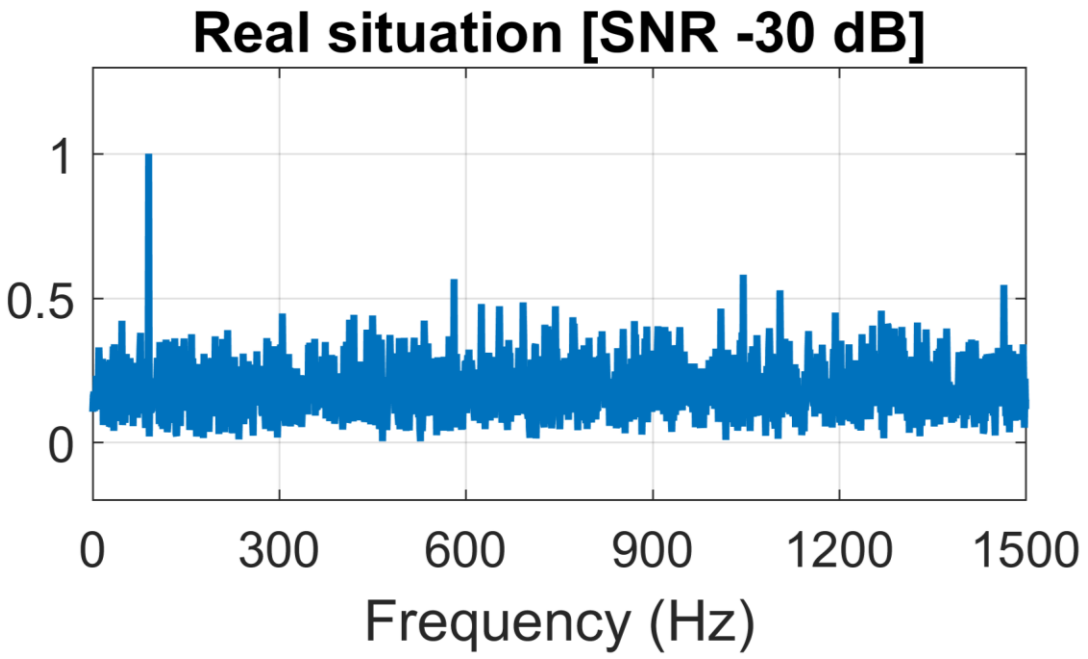




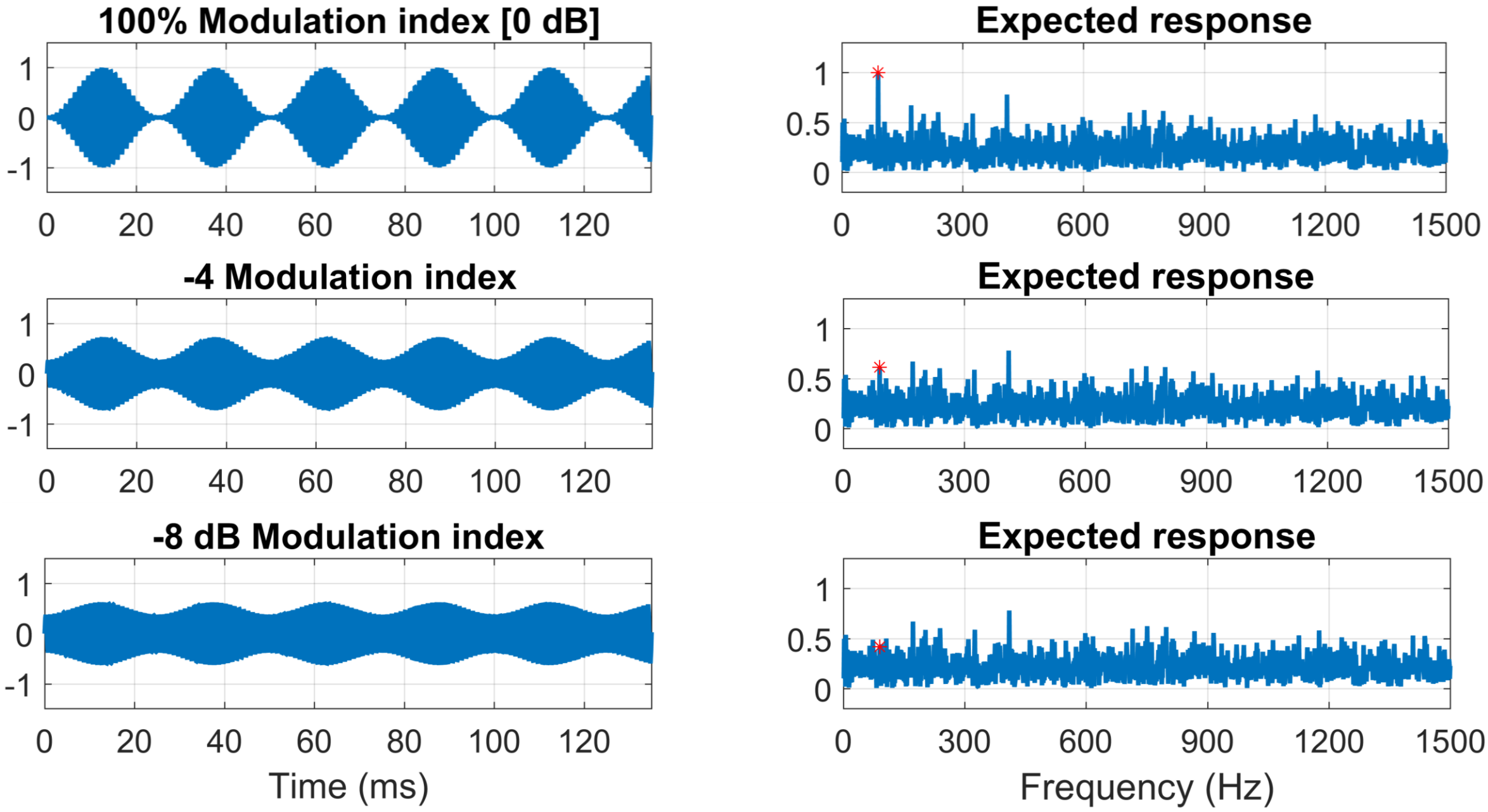

Quiet - Simulation
2
0
-2
0
20
40
60
80
100
120
Time (ms)

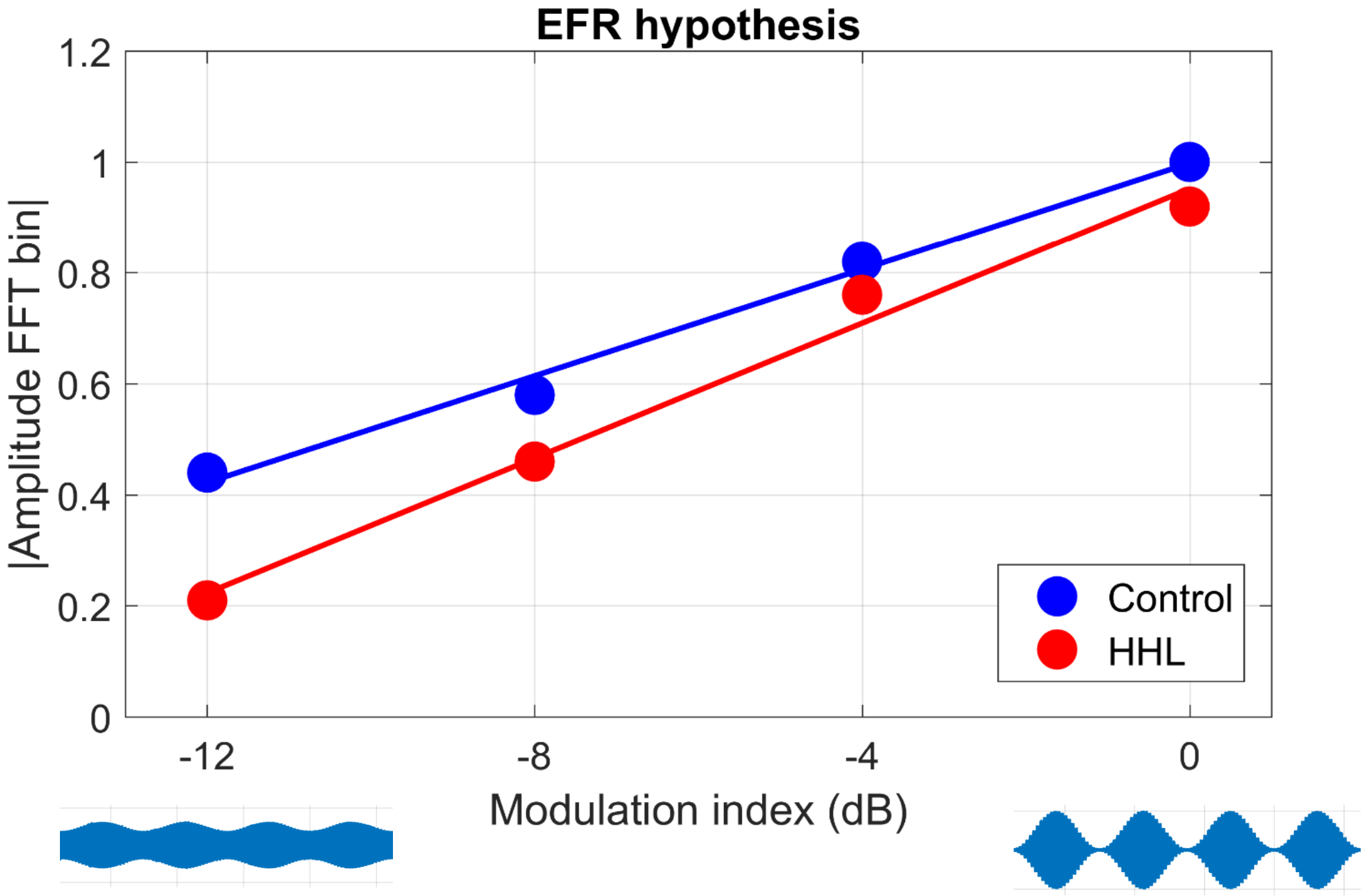

Quiet - Simulation
F0 = 90 Hz
F1 = 2*F0
1
0.5
0
0
300
600
900
1200
1500
Frequency (Hz)


Real situation [SNR -30 dB]
40
20
0
-20
-40
0
20
40
60
80
100
120
Time (ms)


Real situation [SNR -30 dB]
1
0.5
0
0
300
600
900
1200
1500
Frequency (Hz)

Hypothesis


100% Modulation index [0 dB]
Expected response
-4 Modulation index
Expected response
-8 dB Modulation index
Expected response
Time (ms)
Frequency (Hz)


EFR hypothesis
1.2
1
0.8
0.6
0.4
0.2
0
|Amplitude FFT bin|
-12
-8
-4
0
Modulation index (dB)
Control
HHL

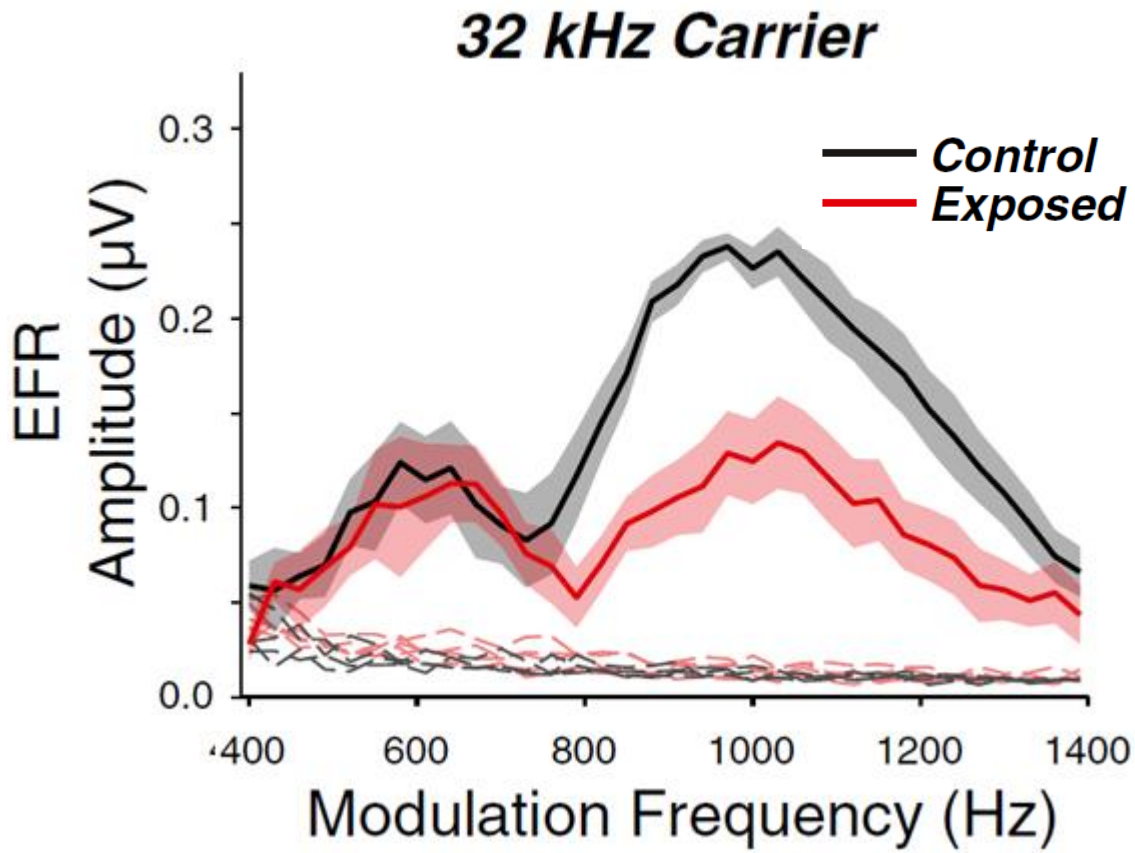
JARO 16: 727–745 (2015)
DOI: 10.1007/s10162-015-0539-3

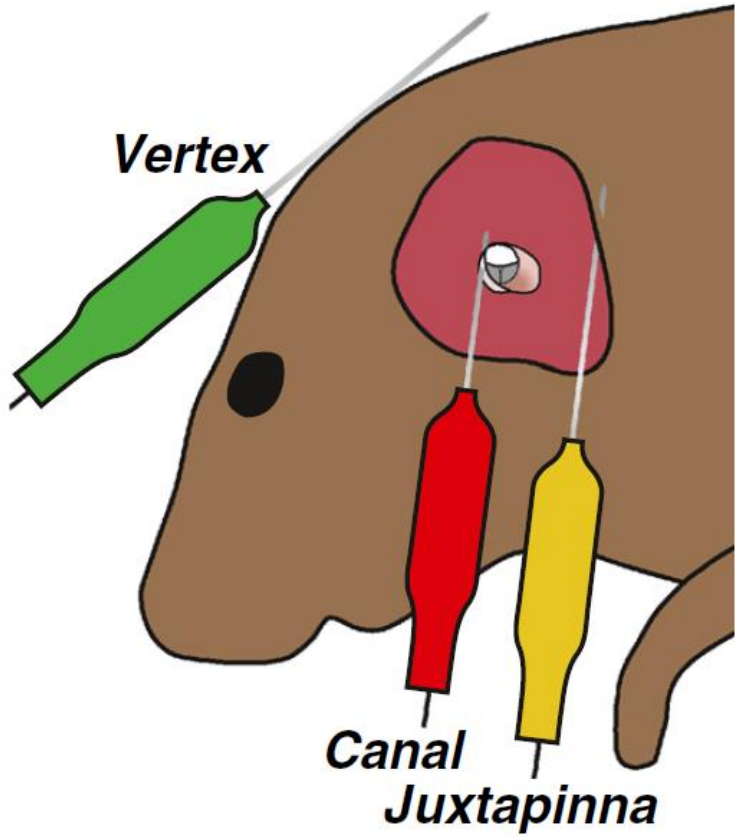
JARO
Journal of the Association for Research in Otolaryngology

Research Article

Towards a Diagnosis of Cochlear Neuropathy with Envelope Following Responses

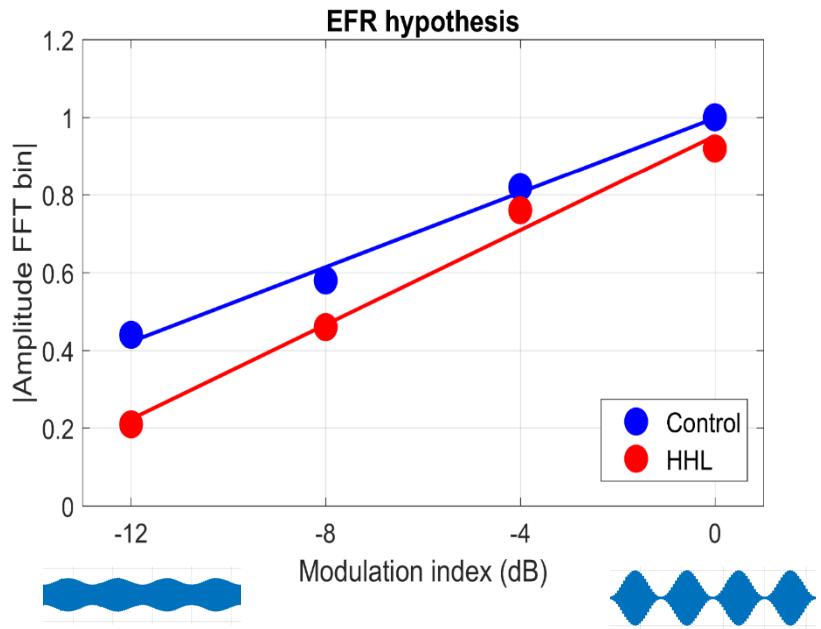
Luke A. Shaheen,[1,2] Michelle D. Valero,[2,3] and M. Charles Liberman[1,2,3]

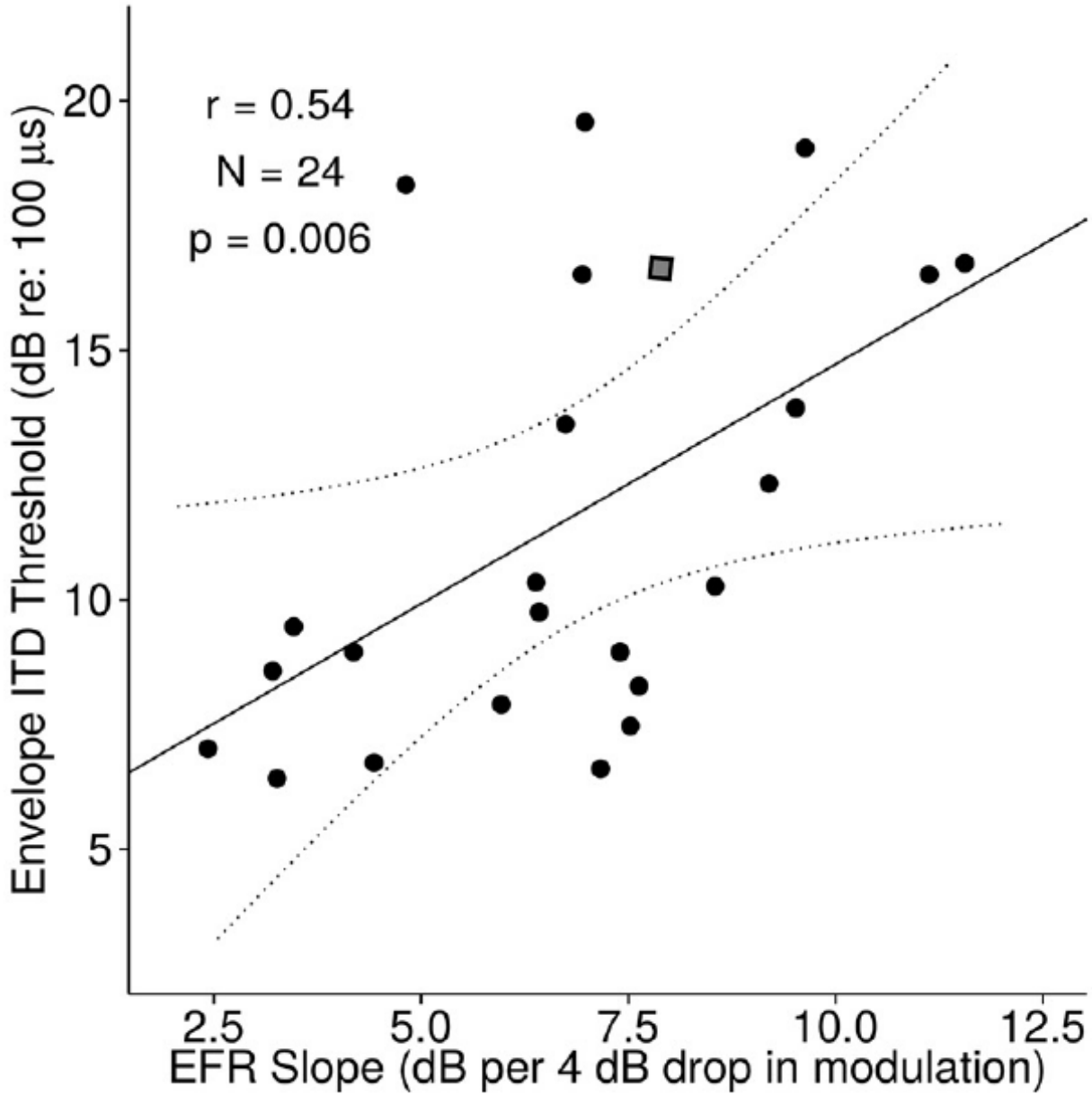




Individual Differences Reveal Correlates of Hidden Hearing Deficits

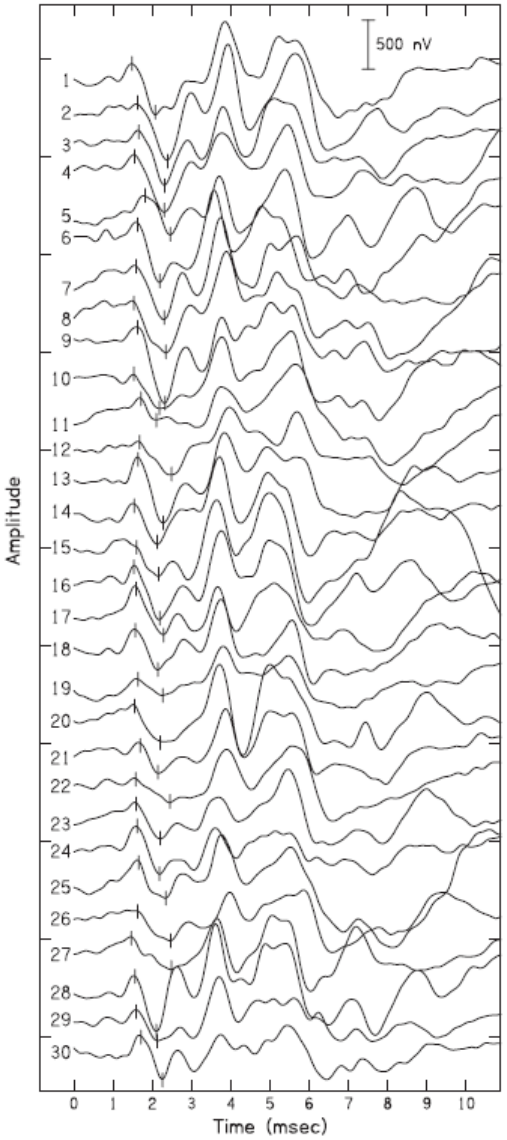
Hari M. Bharadwaj,[1,2] Salwa Masud,[1,2] Golbarg Mehraei,[1,3] Sarah Verhulst,[1,4] and Barbara G. Shinn-Cunningham[1,2]

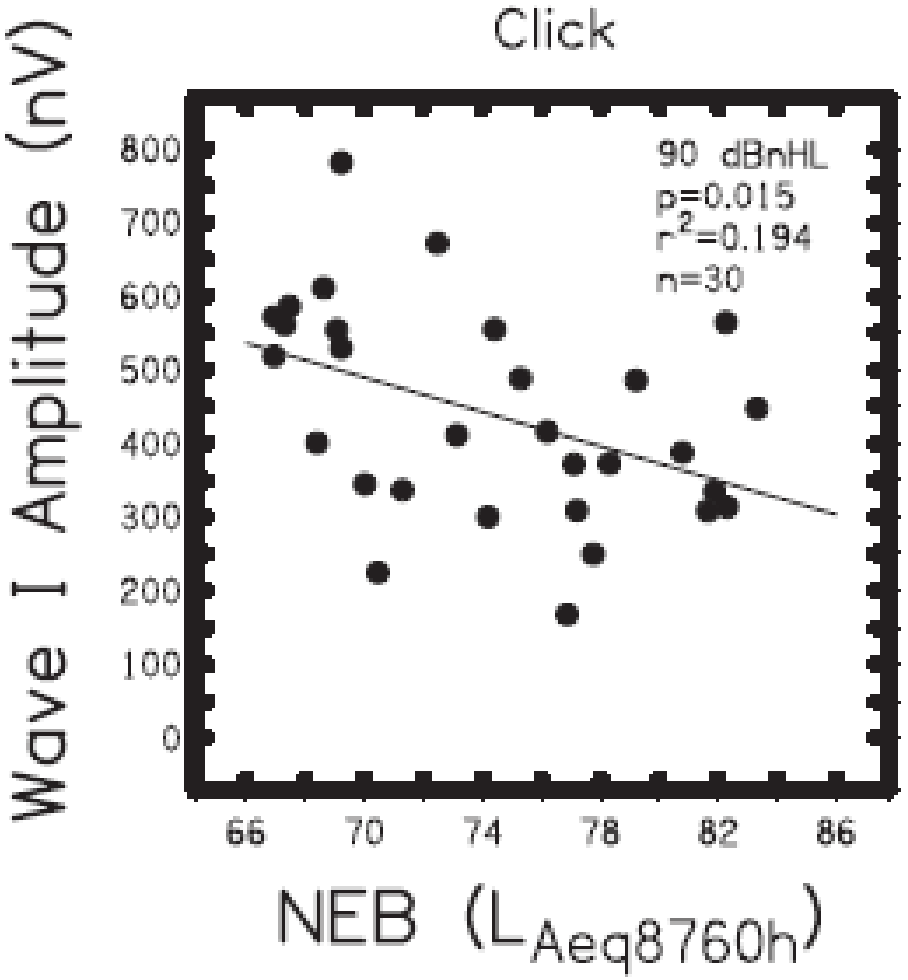


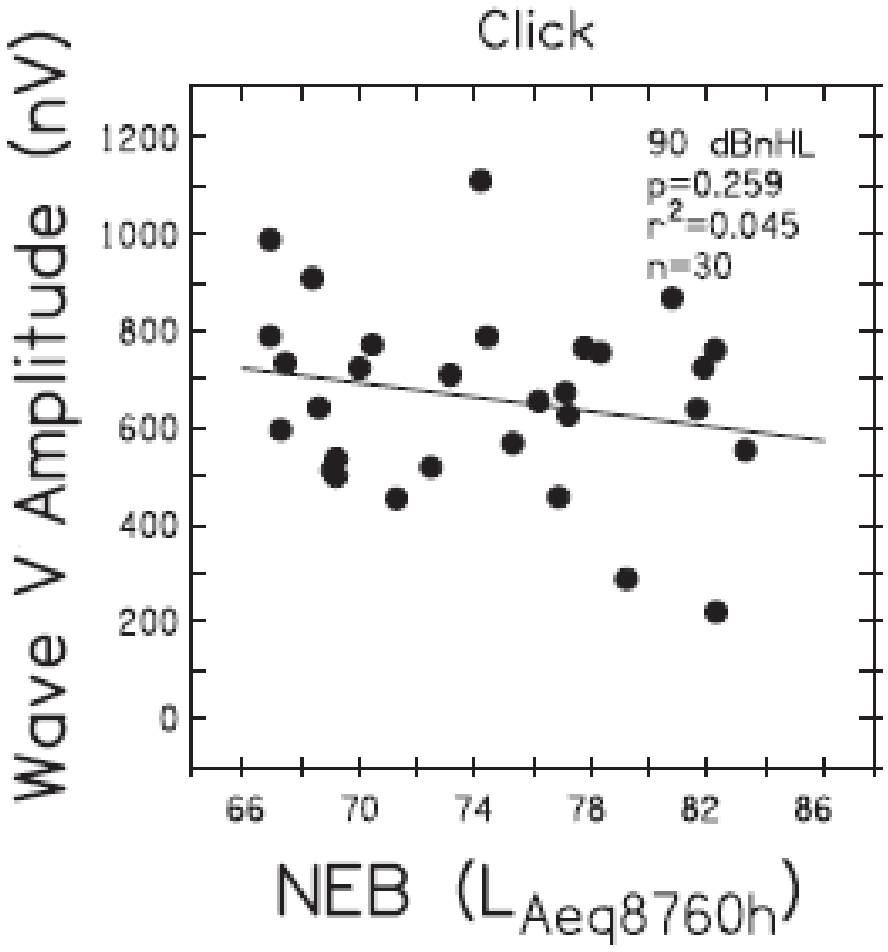


STAMPER AND JOHNSON / EAR & HEARING, VOL. 36, NO. 2, 172–184

Auditory Function in Normal-Hearing, Noise-Exposed Human Ears

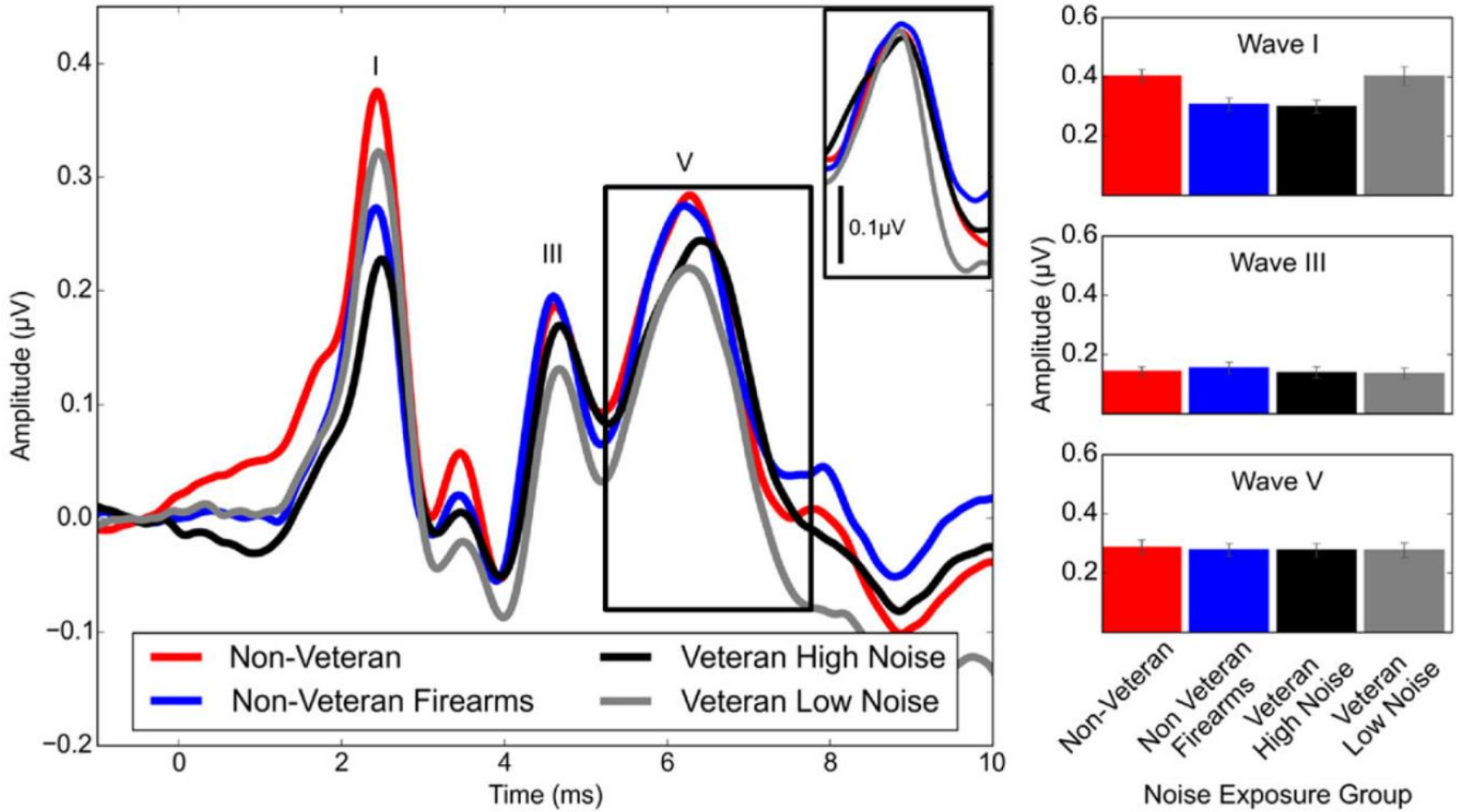






Auditory Brainstem Response Altered in Humans With Noise Exposure Despite Normal Outer Hair Cell Function

Naomi F. Bramhall[1], **Dawn Konrad-Martin**[1,2], **Garnett P. McMillan**[1], and **Susan E. Griest**[1,2]

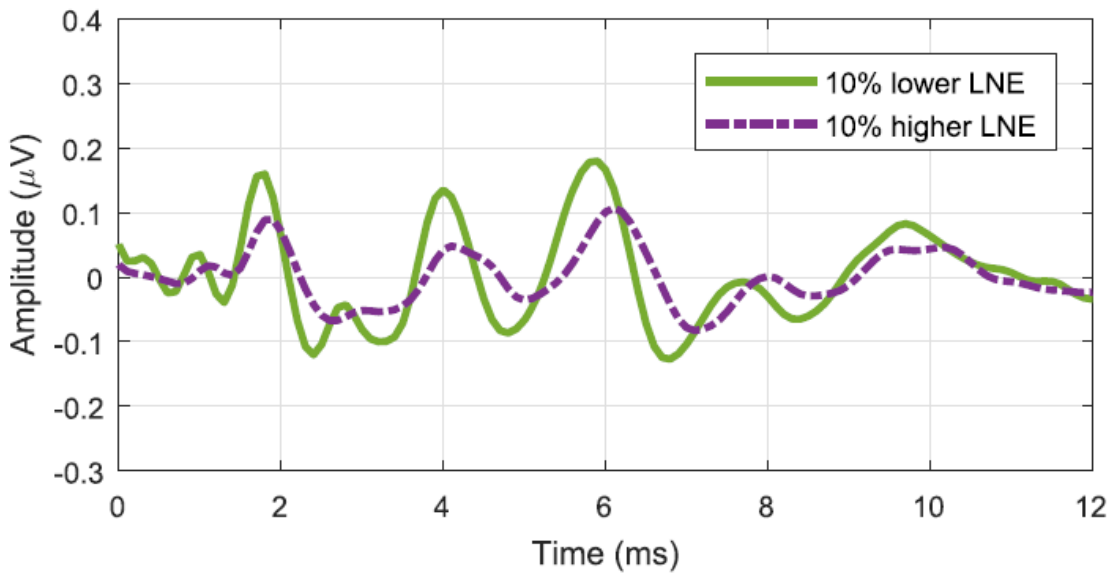


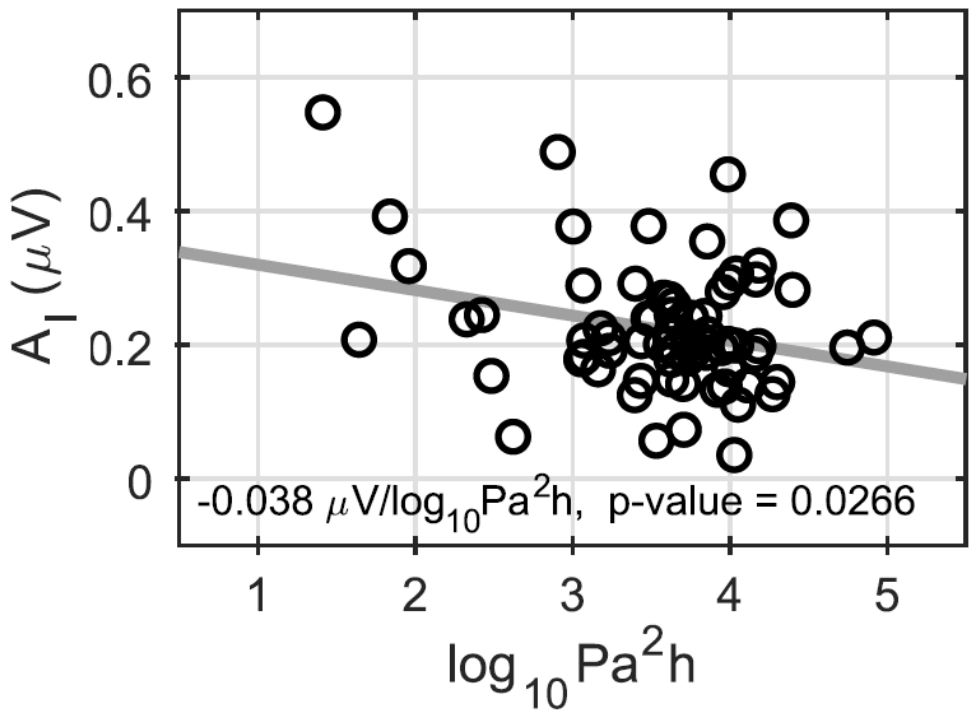
Research Paper

Hearing Research 365 (2018) 36–48

Effects of lifetime noise exposure on the middle-age human auditory brainstem response, tinnitus and speech-in-noise intelligibility

Joaquin T. Valderrama [a, b, c, *], Elizabeth Francis Beach [a, c], Ingrid Yeend [a, b, c], Mridula Sharma [b, c], Bram Van Dun [a, c], Harvey Dillon [a, c]



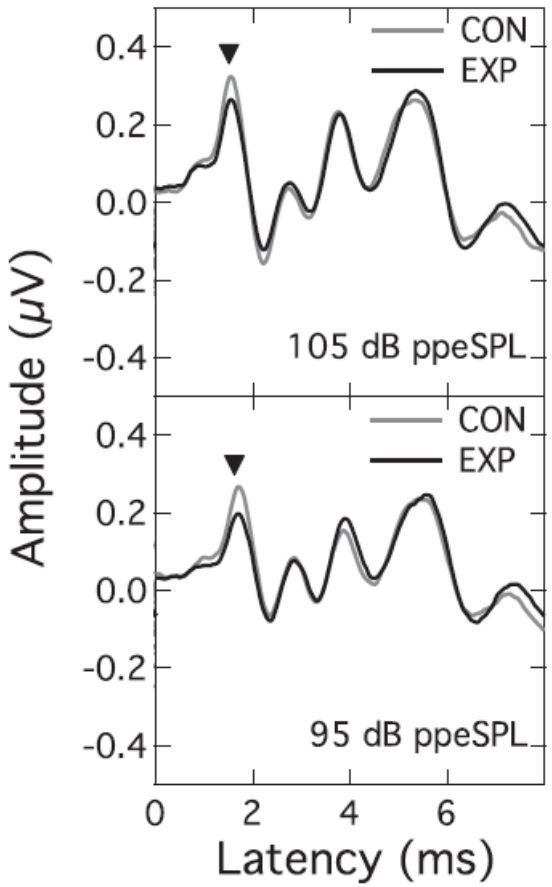


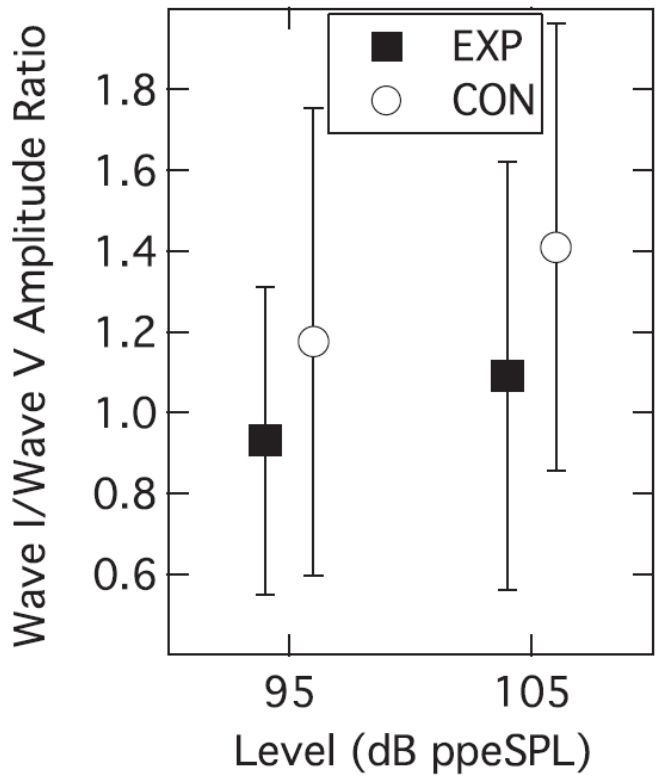
Trends in Hearing
Volume 21: 1–18

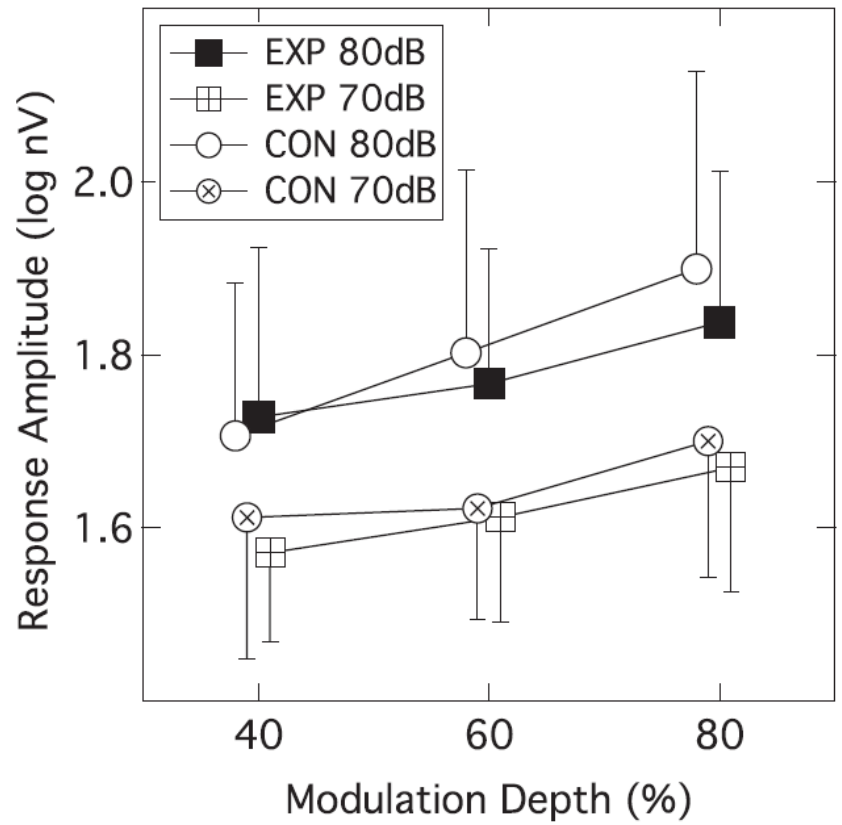
DOI: 10.1177/2331216517737417
journals.sagepub.com/home/tia
SAGE

Loud Music Exposure and Cochlear Synaptopathy in Young Adults: Isolated Auditory Brainstem Response Effects but No Perceptual Consequences

John H. Grose[1], Emily Buss[1], and Joseph W. Hall III[1]

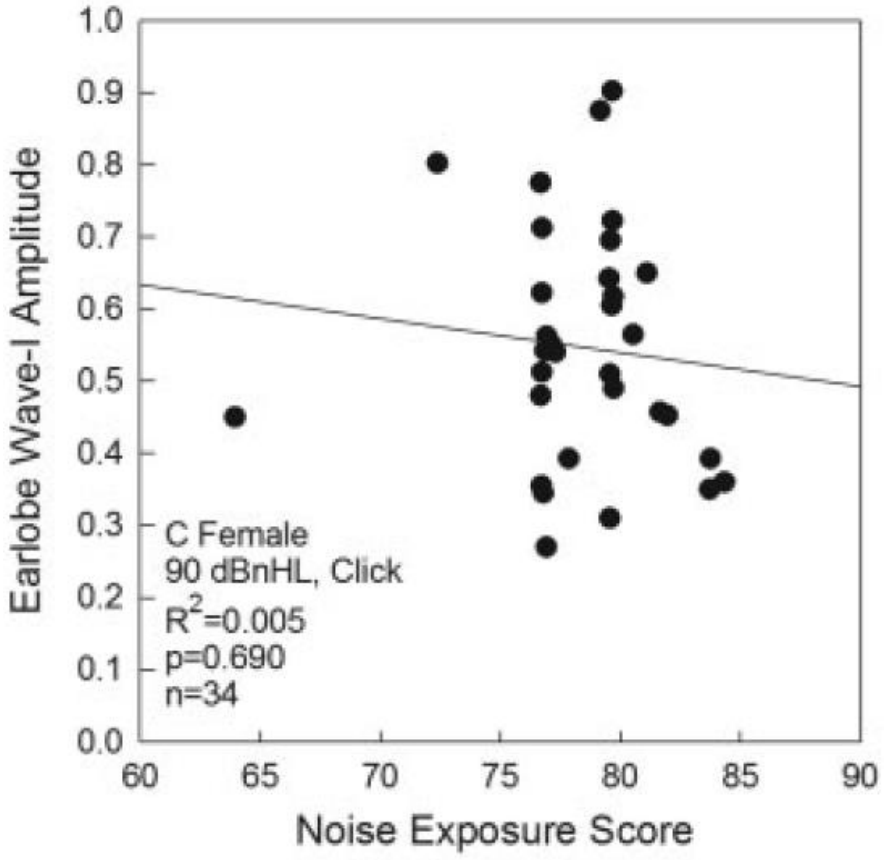


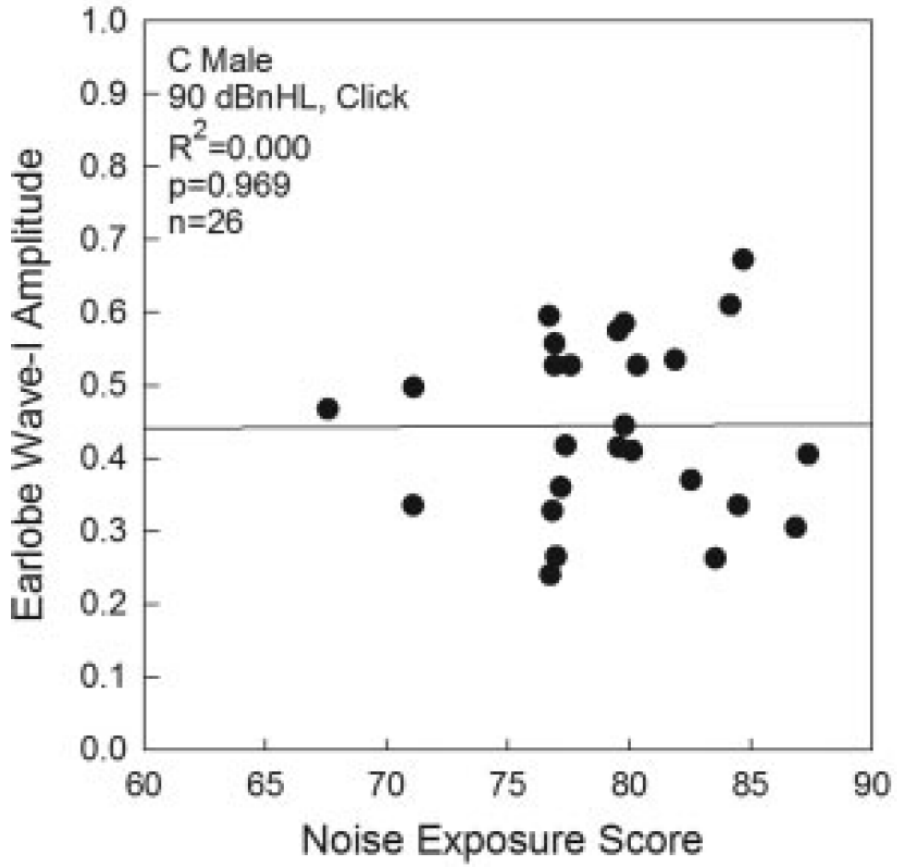




Effects of Recreational Noise on Threshold and Suprathreshold Measures of Auditory Function

Angela N.C. Fulbright, Au.D., Ph.D.,[2] Colleen G. Le Prell, Ph.D.,[1] Scott K. Griffiths, Ph.D.,[2] and Edward Lobarinas, Ph.D.[1]

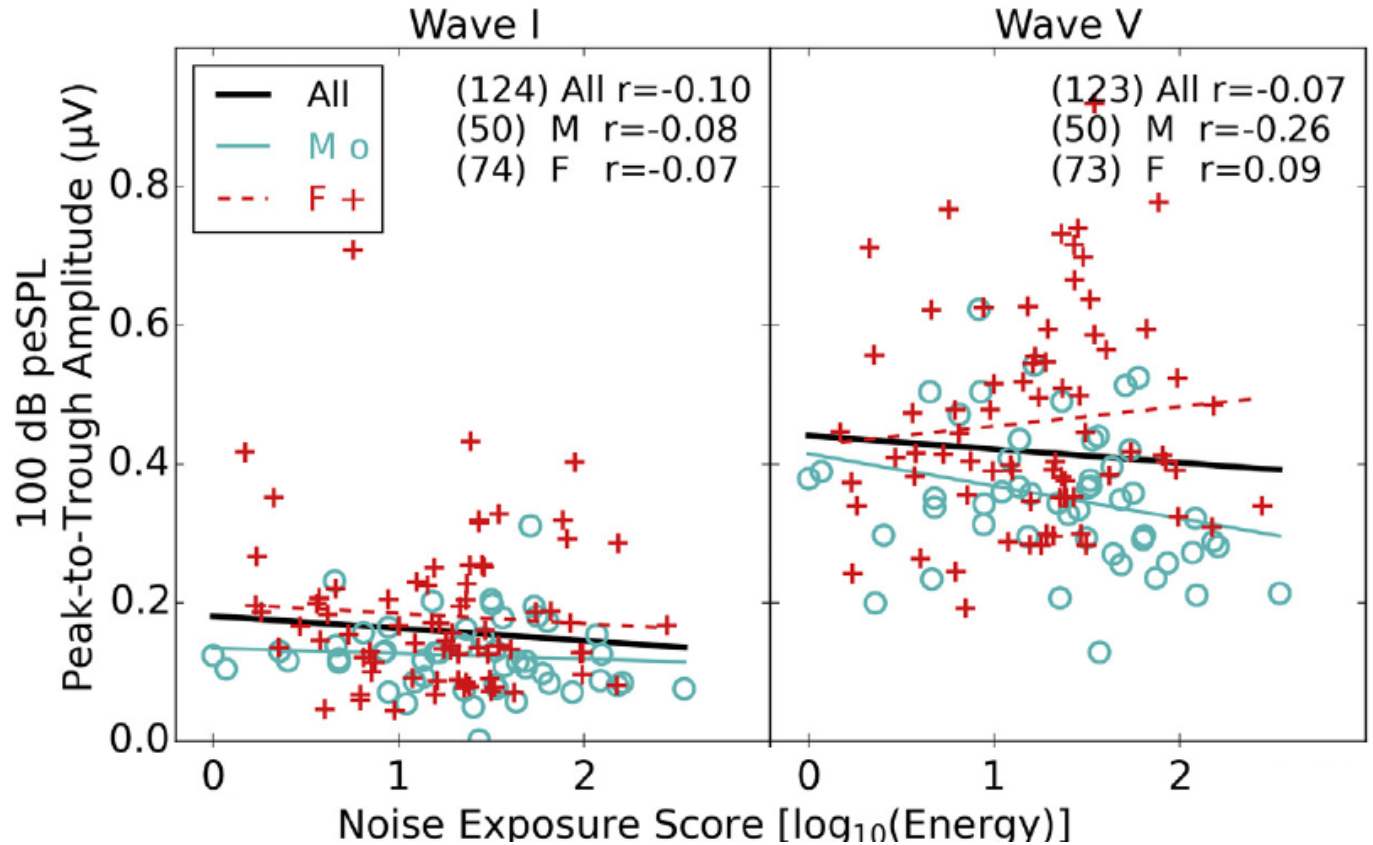




Research Paper

Effects of noise exposure on young adults with normal audiograms I: Electrophysiology

Garreth Prendergast [a, *], Hannah Guest [a], Kevin J. Munro [a, b], Karolina Kluk [a], Agnès Léger [a], Deborah A. Hall [c, d], Michael G. Heinz [e], Christopher J. Plack [a, f]

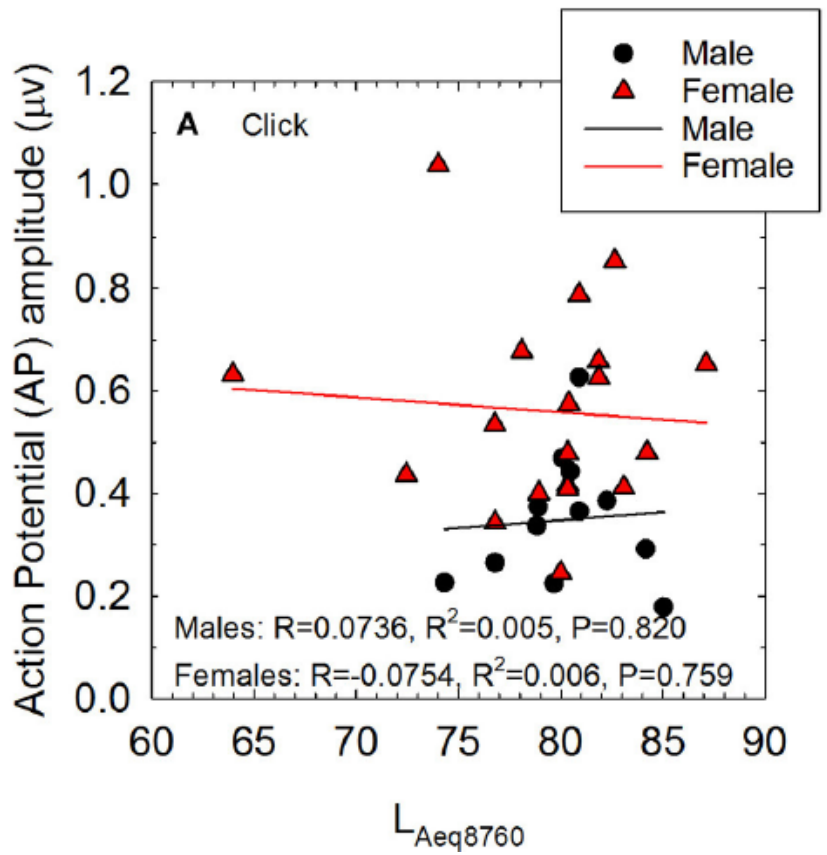


frontiers in Neuroscience

ORIGINAL RESEARCH
published: 01 September 2017
doi: 10.3389/fnins.2017.00465

Hidden Hearing Loss? No Effect of Common Recreational Noise Exposure on Cochlear Nerve Response Amplitude in Humans

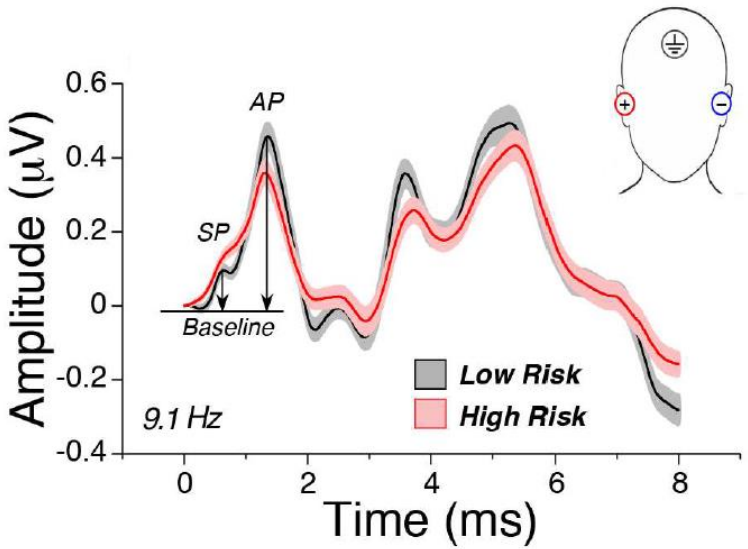
*Sarah K. Grinn[1,2], Kathryn B. Wiseman[1], Jason A. Baker[1] and Colleen G. Le Prell[1]**

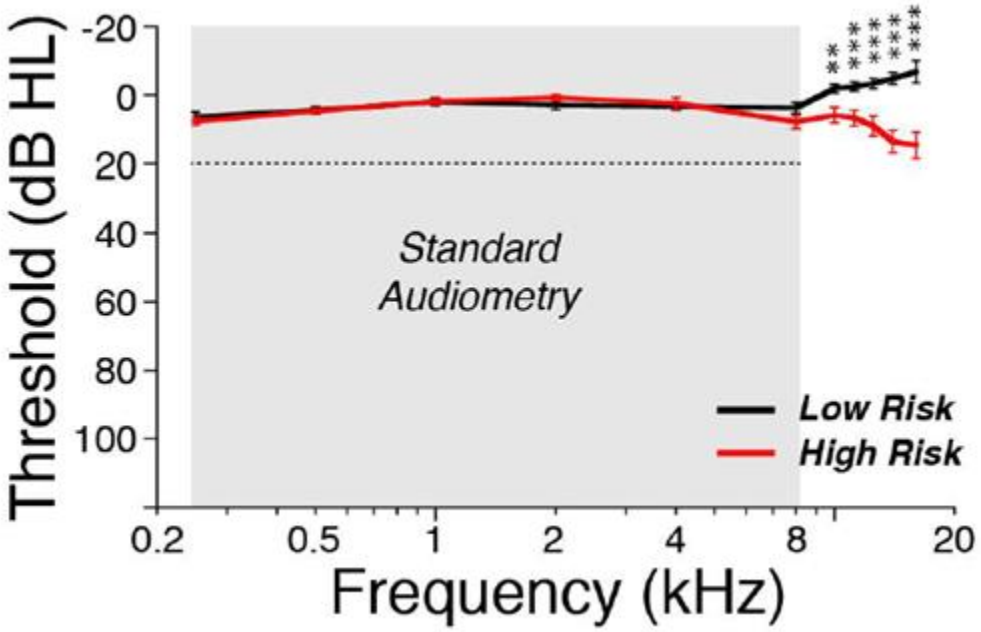


PLOS ONE

Toward a Differential Diagnosis of Hidden Hearing Loss in Humans

M. Charles Liberman[1,2,3], Michael J. Epstein[4], Sandra S. Cleveland[4], Haobing Wang[2], Stéphane F. Maison[1,2,3]*





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Round-window delivery of neurotrophin 3 regenerates cochlear synapses after acoustic overexposure

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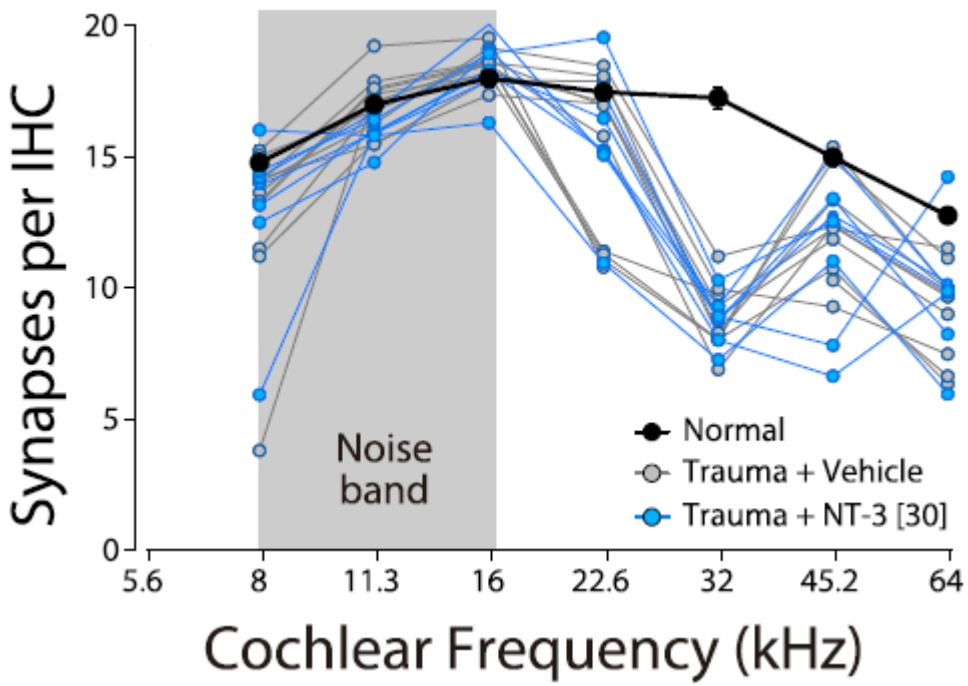

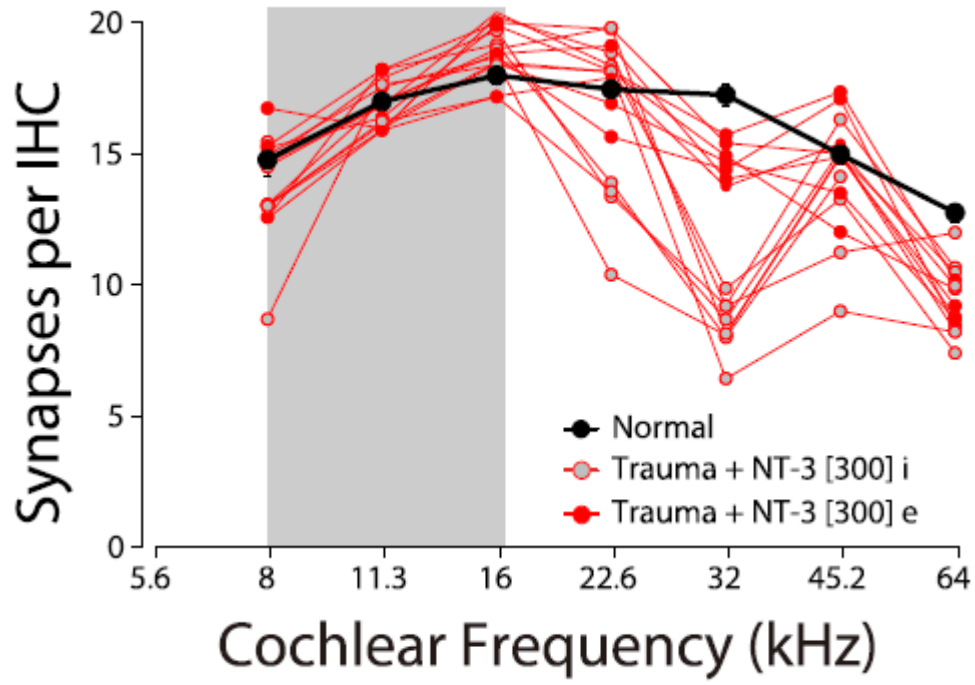

Summary

- ✓ Diagnosing HHL in humans is a hot topic
  - ✓ Large variability of results
- ✓ There are some evidences of HHL in humans
- ✓ Diagnosing HHL is not easy
  - Animal models may differ from humans
  - Non-invasive methods are subject to many confounding variables
  - Lack of validation
- ✓ Future
  - Results replication
  - Explore new diagnosis methods

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