Peripheral and Central Auditory Deficits Following Continuous Noise Exposure

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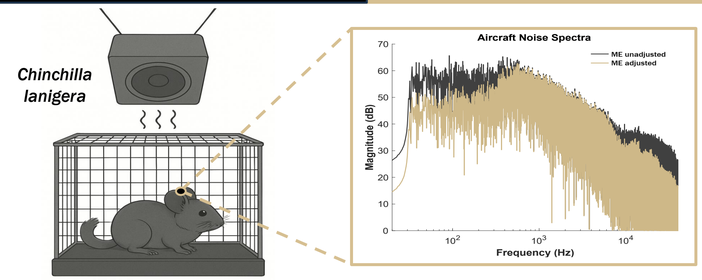
Overview

Service members encounter damaging sounds throughout their careers—from continuous noise to brief high-intensity blasts (e.g., improvised explosive devices). In this study, we measured hearing thresholds, temporal processing to a modulated tone (f_c = 4 kHz, f_m = 223 Hz), cochlear function (DPOAE + SFOAE), and acoustic reflex (WB-MEMR) following continuous noise exposure up to 4 weeks (40 hours/week at 87.5 dBA) simulating aircraft carrier conditions. Our primary objective is to identify auditory-based biomarkers, supported by histology, to differentiate noise- and blast-induced hearing loss profiles.



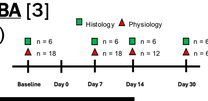
MOTIVATION

- **Hearing loss is the most common service-related disability in U.S. veterans [1]**
  - Acoustic exposure diversity (continuous noise vs blast)
  - Comorbidities: *traumatic brain injury (TBI), post-traumatic stress disorder (PTSD), anxiety, depression, addiction, etc.*
  - Compromised in-service and post-service communication
- **Pure tone audiometry often misses hidden hearing loss** [2]
- **Preclinical findings are challenging to translate**
  - Species noise vulnerability differences
  - Mostly investigated short-term exposures (~2 hours)
  - Limited functional assessment paired with histology

Primary Objective: Characterize **functional** and **structural** auditory effects across species (chinchilla, rat, human) following **continuous noise** and **blast exposure**

NOISE EXPOSURE

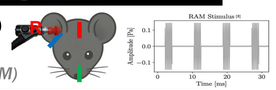
- Occupational *aircraft carrier* exposure at **87.5 dBA** [3]
- **4 days/week** for 1, 2, or 4 weeks (**10 hours/day**)
- Middle-ear (ME) adjustment → dBA to dB(Chin)
- 33% group size loss due to histology (N = 18)



FUNCTIONAL ASSESMENT

1. Auditory Brainstem Response (ABR)
2. Envelope Following Response (EFR)

Rectangular Amplitude Modulation (RAM)



	ABR	EFR (RAM)	
Stimulus	0.5 – 8 kHz	F_c = 4 kHz	F_m = 223 Hz
Stimulus Level (dB SPL)	0 – 80 (Δ = 10 dB)	65 and 80	
Analysis	Subaverage Cross-correlation [4]	Phase Locking Value (PLV) Total Sum	
Anesthesia (SQ)	Xylazine (4 mg/kg) + Ketamine (20 mg/kg)		

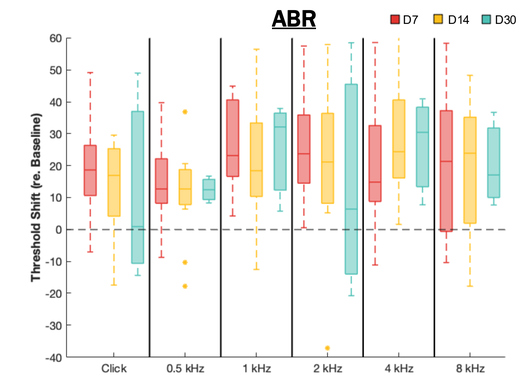
3. Wide-band Middle Ear Muscle Reflex (WB-MEMR) [5]

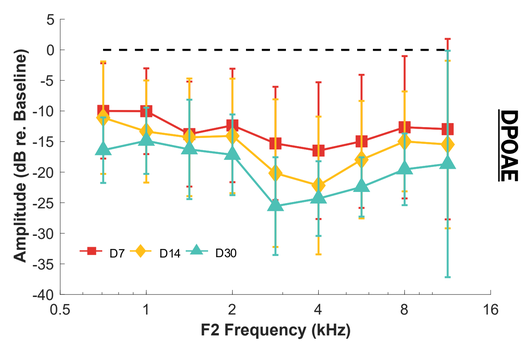
	WB-MEMR	
Stimulus	Probe: Click (c_{1-7})	Elicitor: Broadband Noise (0.5 – 8 kHz)
Stimulus Level (dB SPL)	90	45–105 (Δ = 6 dB)
Analysis	Immittance Change: c_1 vs c_{2-7}	

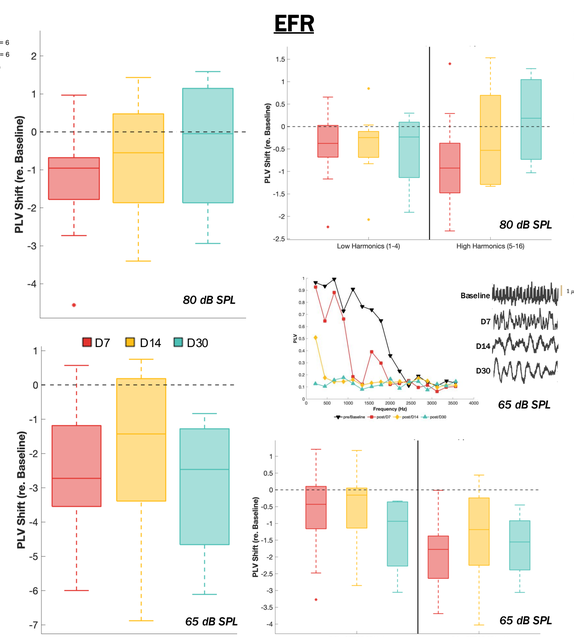
4. Swept Otoacoustic Emissions [6]

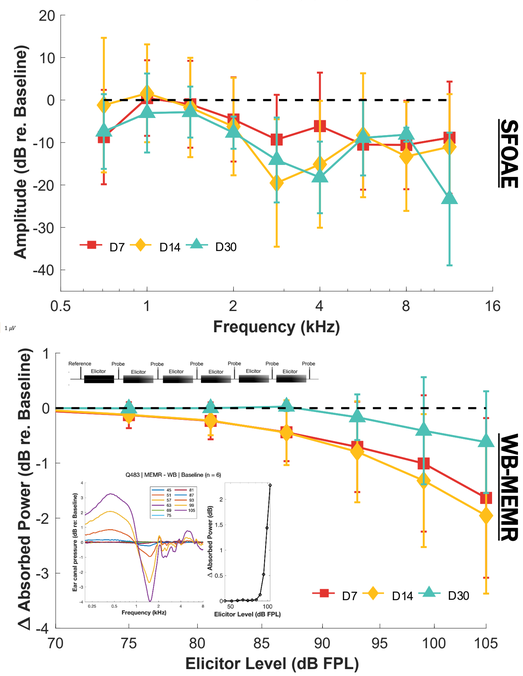
	DPOAE		SFOAE	
Frequency Range	F_2: 0.5 – 16 kHz		F_{probe}: 0.5 – 16 kHz	
Sweep Direction	Upward (1 oct/sec)		Downward (1 oct/sec)	
Stimulus Level (dB FPL)	F_2 = 75	F_1 = 85	F_{probe} = 40	$F_{supressor}$ = 60
Frequency Relationship	F_2/F_1 = 1.22		$F_{probe} - F_{supressor}$ = 50 Hz	
Analysis	Least Squares Fit (6 dB SNR)			

RESULTS









KEY FINDINGS

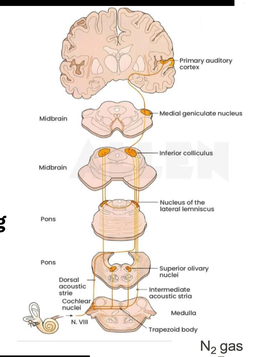
Permanent Peripheral Deficits

- ***Sustained mild-to-moderate hearing loss***
  - Primarily affecting high frequencies
  - Permanent threshold shifts: 10-40 dB
- ***Sustained impaired hair cell function***
  - ↓ DPOAE amplitudes: 5-25 dB
  - ↓ SFOAE amplitudes: 5-10 dB

Temporary Central Deficits

- ***Recovery of suprathreshold auditory processing***
  - ↓ WB-MEMR strength
  - ↓ EFR temporal synchronicity

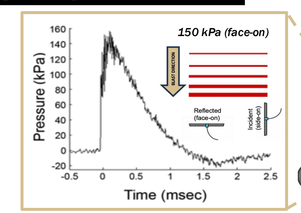
Here, we show that **continuous noise** exposure *at moderate levels* induces **permanent peripheral** auditory deficits with signs of **subcortical recovery**.



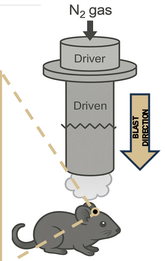
FUTURE STEPS

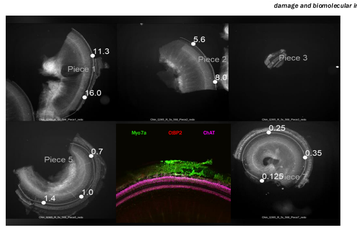
Blast Exposure

- Top-down shock tube
  - Single blast
  - Transient (< 3 ms)
  - Binaural protection
- Blast dosage
  - Shockwave injury
  - Low mortality
  - Subacute hearing loss



The proposed shock tube can deliver consistent blast profiles at 75 and 150 kPa peak overpressure, which has been shown to induce mild traumatic brain injury (mTBI) characterized by microstructural damage and biomolecular imbalance despite the absence of sensory-motor and memory loss [7]





Chinchilla cochlear frequency mapping (Courtesy of Dr. Jane Mondul)

Structural Assessment

Peripheral
Hair cell survival: Phalloidin
Synaptic counts: CtBP2+GluR2

Central
Axonal integrity: Nf-L
Glial activation: GFAP, Iba-1
Neuroinflammation: TNF-α

References: *[1]* U.S. Department of Veteran Affairs. "Hearing Loss Fact Sheet". August 2021. *[2]* Kujawa and Liberman. "Adding Insult to Injury: Cochlear Nerve Degeneration after 'Temporary' Noise-Induced Hearing Loss." November 11, 2009. *[3]* Komrower et al. "Noise Control on U.S. Navy Aircraft Carriers". *[4]* Shaheen et al. "ABRpresto: An Algorithm for Automatic Thresholding of the Auditory Brainstem Response Using Resampled Cross-Correlation across Subaverages." November 3, 2024. *[5]* Bharadwaj et al. "Cross-Species Experiments Reveal Widespread Cochlear Neural Damage in Normal Hearing." July 22, 2022. *[6]* Hauser et al. "Cross-Species Characterization of Joint Otoacoustic Emission Profiles in Sensorineural Hearing Loss." March 1, 2023. *[7]* Walls et al. "Structural and Biochemical Abnormalities in the Absence of Acute Deficits in Mild Primary Blast-Induced Head Trauma." March 2016. *[8]* Keshishzadeh et al. "Towards Personalized Auditory Models: Predicting Individual Sensorineural Hearing-Loss Profiles From Recorded Human Auditory Physiology." January 2021.

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