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Effects of noise exposure on young adults with normal audiometric thresholds

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BACKGROUND

Noise-induced cochlear synaptopathy

- Destruction of synapses between inner hair cells and auditory nerve fibres[1]
- Demonstrated in mice, rats, chinchillas, guinea pigs, and macaques[1,2]
- Can occur without widespread hair cell loss or permanent threshold elevation[1,2]
- Suggested as a cause of perceptual deficits in humans with normal audiograms[1,3]

Possible measures of cochlear synaptopathy

- Electrophysiological measures, e.g. the amplitude of wave I of the auditory brainstem response (ABR) and the envelope-following response (EFR)
- Basic psychoacoustic tasks, e.g. amplitude modulation detection (AMD), interaural phase difference discrimination (IPD), frequency difference limens (FDL), intensity difference limens (IDL), auditory localisation
- More complex behavioural tasks, e.g. speech perception in noise
- Middle-ear muscle reflex (MEMR); functional magnetic resonance imaging (fMRI)

FIVE RELATED PROJECTS (2014-19)

All aimed to test for evidence of cochlear synaptopathy in young adults with normal audiometric thresholds from 0.25 to 8 kHz and normal middle-ear function:

Project	*Predictors*	*Outcome measures*	*Reported in...*
Project 1 (lead researcher G Prendergast)	Lifetime noise exposure	ABR amplitude EFR amplitude Speech in noise AMD, ITD, FDL, and IDL Localisation Musical consonance	*Prendergast et al. (2017a)*[4] *Prendergast et al. (2017b)*[5]
Project 2 (lead researcher H Guest)	Tinnitus Impaired speech perception	ABR and EFR amplitude Lifetime noise exposure	*Guest et al. (2017)*[6] *Guest et al. (2018a)*[7] *Guest et al. (2018b)*[8]
Project 3 (lead researcher S Couth)	Lifetime noise exposure (musicians)	ABR amplitude Speech in noise	
Project 4 (lead researcher R Dewey)	Lifetime noise exposure	ABR amplitude fMRI	*Dewey et al. (2018)*[9]
Project 5 (lead researcher W Tu)	Lifetime noise exposure	ABR amplitude	*Prendergast et al. (2018)*[10]

SHARED METHODS

Auditory brainstem response (ABR)

- All **five projects** used click stimuli, delivered at between 100 and 115 dB peSPL
- Clicks were presented through ER3A insert earphones at rates of 7 to 11 Hz
- Responses were filtered (low-pass cut-off 1500 Hz, high-pass cut-off 30 to 300 Hz)
- Amplitudes of waves I and V were determined using a peak-picking algorithm

Envelope-following response (EFR)

- **Project 1** and **Project 2** recorded EFRs to transposed tones[11] at 75-80 dB SPL
- f_c = 4 kHz (both projects); f_m ≈ 260 Hz (**Project 1**); f_m = 100 Hz (**Project 2**)

Noise Exposure Structured Interview (NESI)

- All **five projects** used versions of this self-report procedure, which allows estimation of lifetime exposure to activities involving estimated sound levels >80 dBA[6]
- The respondent's life is divided into periods when exposure habits were fairly stable
- For each life period, standardised methods are used to estimate total duration and level of exposure, along with usage and attenuation of hearing protection
- Data are combined to yield units linearly related to total energy of exposure >80 dBA

Coordinate Response Measure (CRM)

- Measure of speech perception in noise[12] used in **Project 1**, **Project 2**, and **Project 3**
- Incorporates multiple talkers, high overall sound levels, and spatial cues
- Target voice at 0° azimuth, two distractor voices at -60° and +60° azimuth
- Distractor voices held at 80 dB SPL and threshold SNR measured for target voice

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5. Prendergast et al. (2017b). Effects of noise exposure on young adults with normal audiograms II: Behavioral measures. *Hear. Res.*
6 Guest et al. (2017). Tinnitus with a normal audiogram: Relation to noise exposure but no evidence for cochlear synaptopathy. *Hear. Res.*
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8. Guest et al. (2018b). Acoustic middle-ear muscle reflex thresholds in humans with normal audiograms: No relations to tinnitus, speech perception in noise, or noise exposure. *In review (Neurosci.)*
9. Dewey et al. (2018). The Physiological Bases of Hidden Noise-Induced Hearing Loss: Protocol for a Functional Neuroimaging Study. *JMIR Res. Protoc.*
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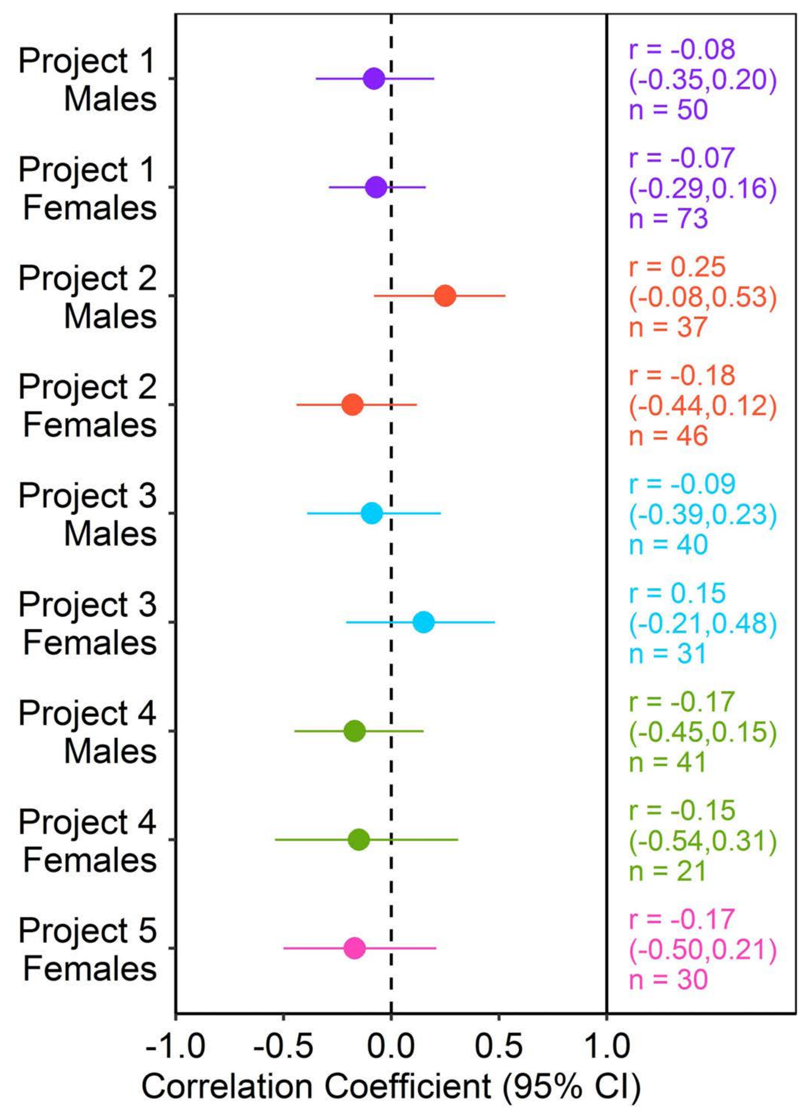
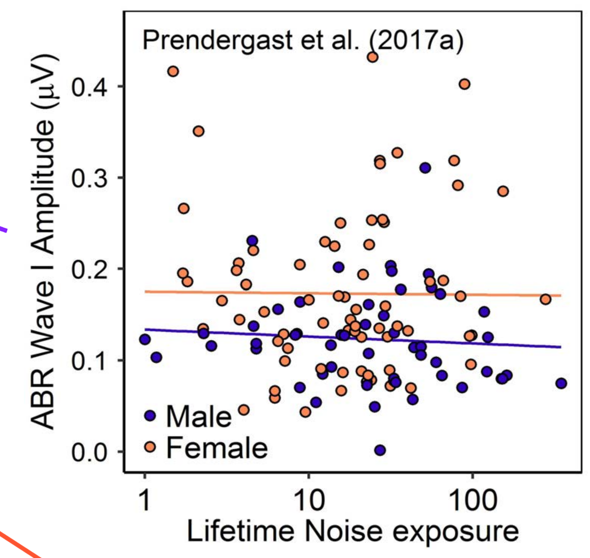
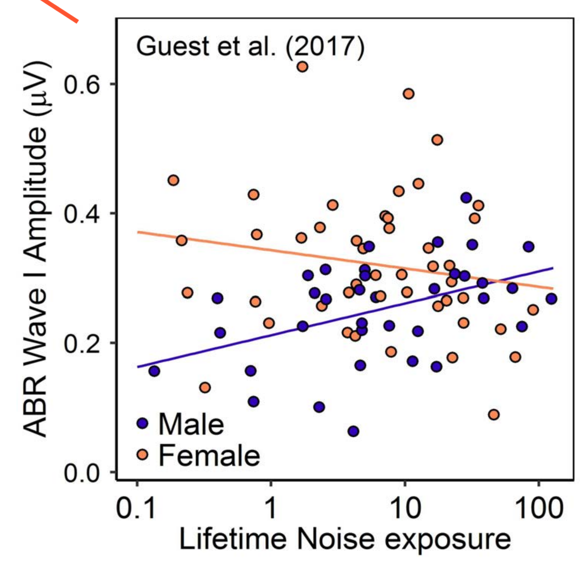
11. Bernstein & Trahiotis (2002). Enhancing sensitivity to interaural delays at high frequencies by using "transposed stimuli". *J. Acoust. Soc. Am.*
12. Kitterick et al. (2010). Benefits of knowing who, where, and when in multi-talker listening. *J. Acoust. Soc. Am.*

RESULTS

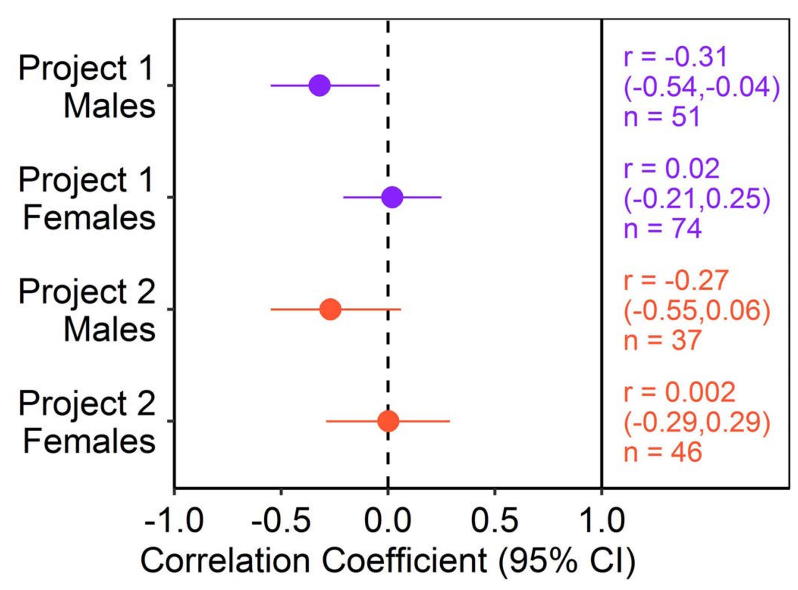
1. No significant relation to ABR wave I amplitude





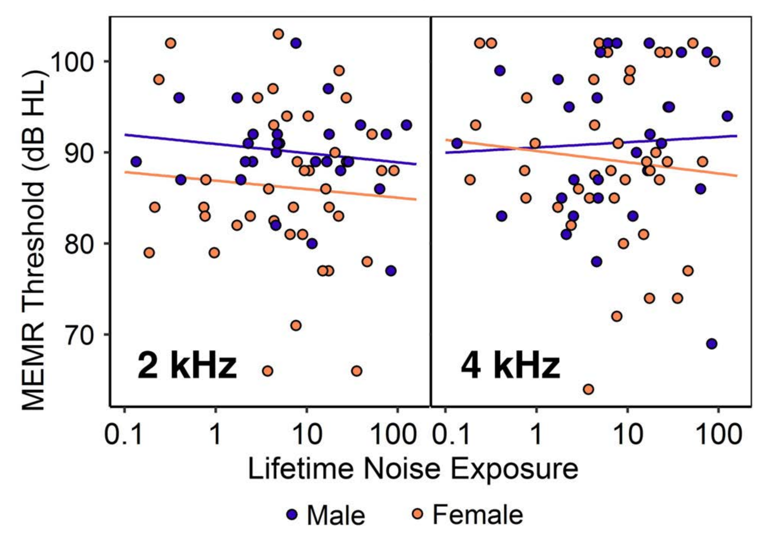


2. No significant relation to EFR amplitude

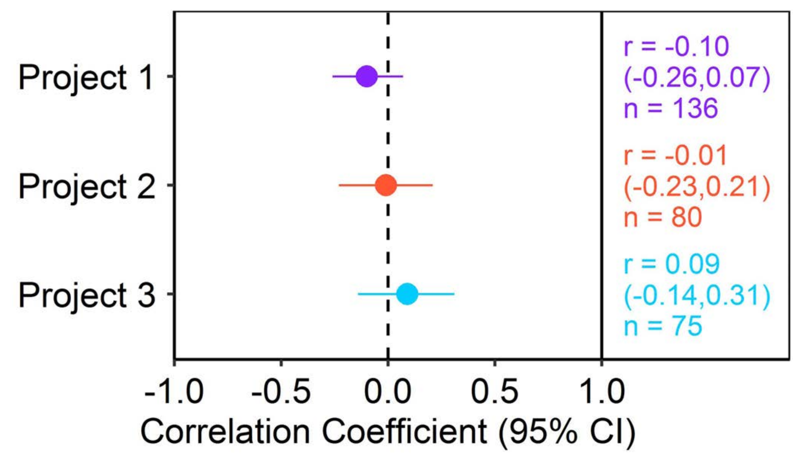


3. No significant relation to MEMR threshold

Guest et al. (2018b)

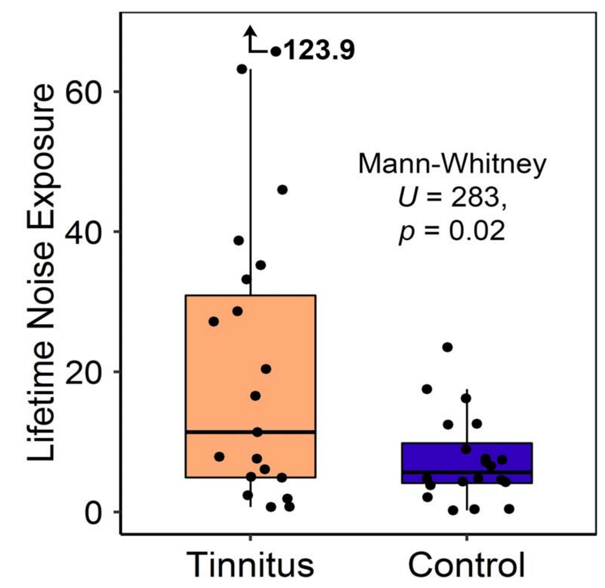


4. No significant relation to CRM (speech in noise)

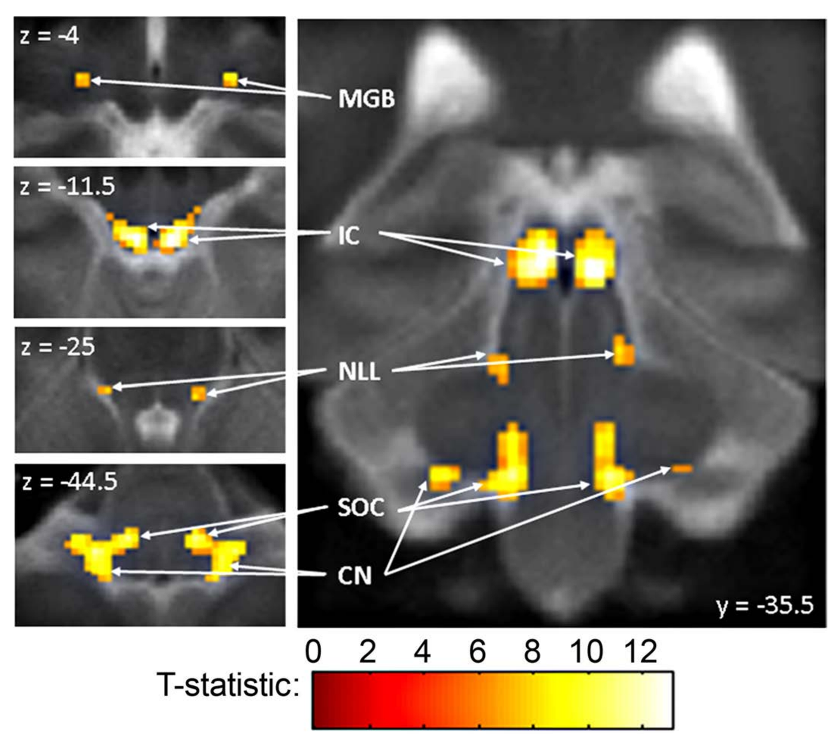


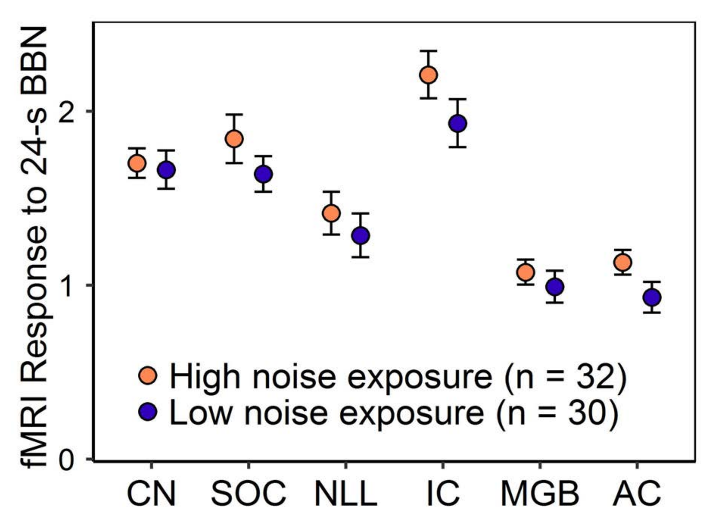
*N.B. Better performance -> lower CRM thresholds, hence a **positive** relation with noise exposure is hypothesised*

5. Significant association with tinnitus



6. No significant association with subcortical or cortical fMRI responses





CN: *Cochlear nucleus*
SOC: *Superior olivary complex*
NLL: *Nucleus of the lateral lemniscus*
IC: *Inferior colliculus*
MGB: *Medial geniculate body*
AC: *Auditory cortex*

CONCLUSIONS

- **In young humans with normal audiograms, we find no evidence that lifetime noise exposure is associated with reduced auditory nerve function, reduced perceptual performance, or changes in fMRI responses**
- **Noise may have the capacity to induce "hidden" changes leading to tinnitus, but we find no evidence that cochlear synaptopathy is one of them**