Upper-Harmonic Deficits in Temporal Envelope Coding of Tone Complexes and Amplitude Modulations Differentiate Inner Hair Cell Damage From Synaptopathy

Poster SU126

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Introduction

The consequences of inner hair cell damage in isolation and how they might overlap with those of cochlear synaptopathy are poorly understood.

- While otoacoustic emissions have paved the way for diagnosing outer hair cell (OHC) dysfunction, there remains to be similar measures of inner hair cell (IHC) and cochlear synapse dysfunction.

- Diagnostics attempting to isolate cochlear synaptopathy could also inadvertently capture the overlapping effects of IHC damage.

- IHC damage and cochlear synaptopathy could also differentially impact the neural coding of amplitude-modulated stimuli and tone complexes, which means both could lead to trouble deciphering speech in noise or dicriminating pitch, but for different reasons.

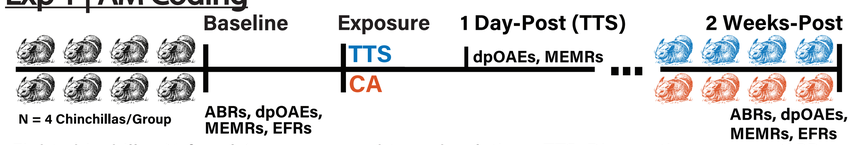
- Here, we utilized animal models of isolated IHC and cochlear synapse damage to differentiate their consequences related to neural envelope coding of modulated stimuli and place-time coding of complex tones.

Methods

Two experiments were conducted. The first was focused on the neural coding of sinusoidal and rectangularly amplitude-modulated stimuli, while the second was focused on the coding of complex tones.

IHC damage was induced (single dose of carboplatin (38 mg/kg)); Synaptopathy: by a temporary threshold shift (TTS, Noise with 1kHz center-freq, 100 dB SPL, 2hrs).

Exp 1 | AM Coding

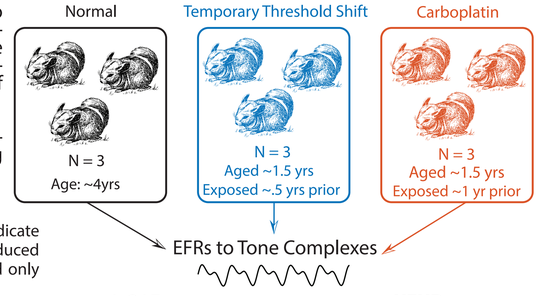


Eight chinchillas (4 female) were exposed to carboplatin or TTS. Diagnostic measures (ABRs, dpOAEs, MEMRs) and electrophysiology (EFRs) were collected before and after exposure.

Exp 2 | Tone-Complex Coding

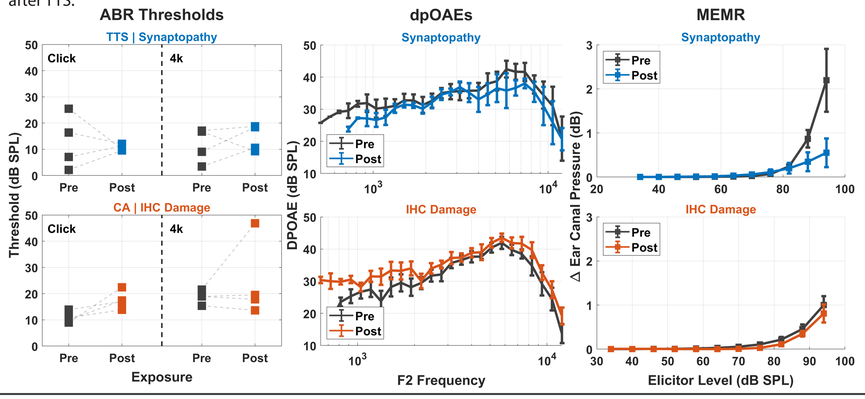
In a follow-up experiment, EFRs to tone complex stimuli were measured to assess how IHC damage and synaptopathy may differentially alter the place-time coding of pitch.

EFRs were then compared to a separate group of normal-hearing chinchillas.



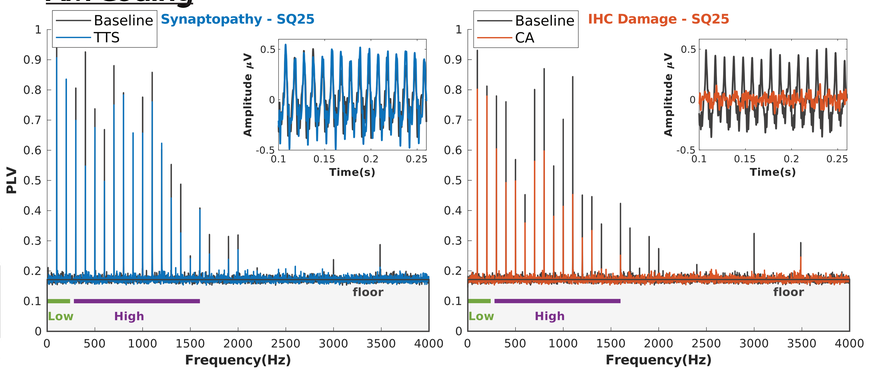
Diagnostic Measures:

Post-exposure assessments did not indicate significant threshold elevation or reduced OAEs. MEMR strength appeared reduced only after TTS.



Results

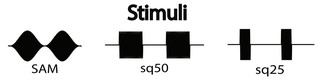
AM Coding

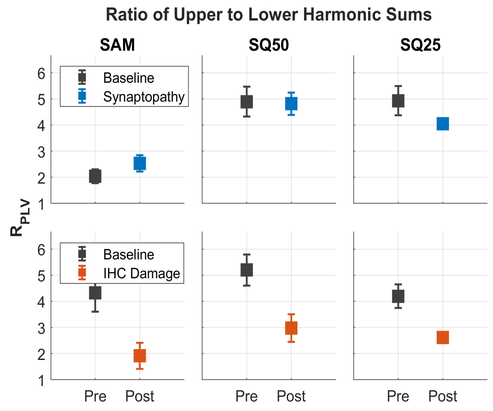


The EFR waveforms of chinchillas with IHC damage appear less temporally sharp in comparison to baseline and synaptopathic chinchillas (above).

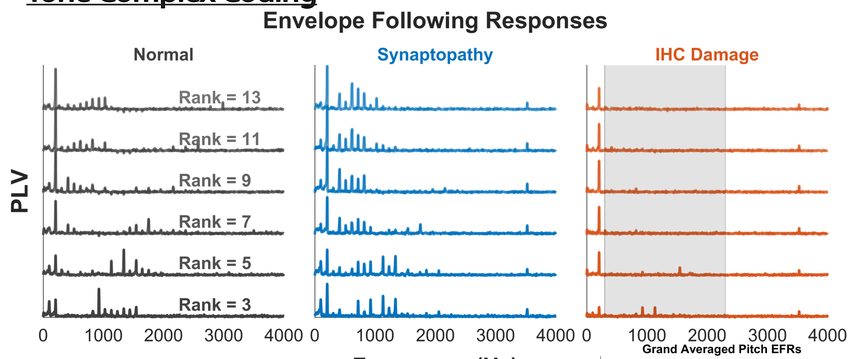
This manifests in a strong and consistent reduction in the upper harmonics of the PLV spectrum of the response, which can be quantified using R_{PLV} (right).

$$R_{PLV} = \frac{\sum_{i=3}^{16} PLV\{h(i)\}}{\sum_{j=1}^{2} PLV\{h(j)\}}$$





Tone Complex Coding



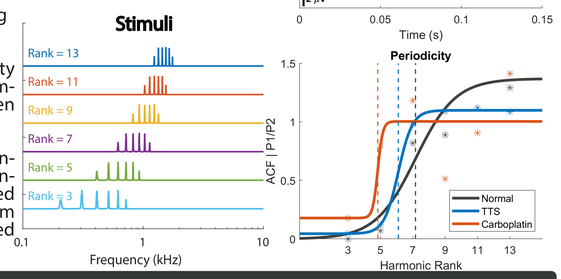
Similar to EFRs in Exp 1, upper harmonics were severely reduced following carboplatin (gray box) for all six stimuli. This is also evidenced by a less "sharp" time waveform (right).

EFRs in the TTS group appear to be unaffected compared to the normal group.

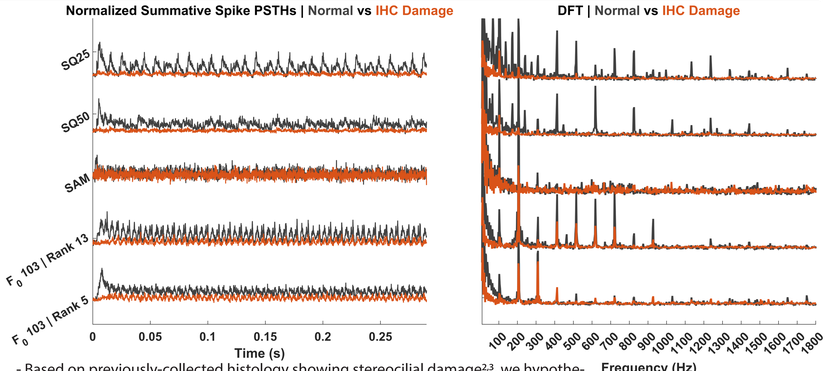
The harmonics in each tone complex were presented in alternating (odd sin, even cos) phase.

This elicits an EFR with periodicity F0 when all harmonics in the complex are resolved, but 2*F0 when harmonics are unresolved[1].

Very slight cochlear place-dependent differences in the resolved-unresolved transition were noticed between groups in these prelim (N=3) data sets. More data needed to test statistical significance.



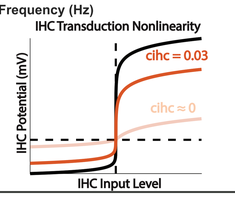
Auditory Nerve Modeling



- Based on previously-collected histology showing stereocilial damage[2,3], we hypothesized that the observed upper harmonic effects in the IHC damaged group could be due to a **flattening of the IHC transduction nonlinearity**, rather than a loss of inner hair cells.

- To test this, we simulated various degrees of inner hair damage (right) using the BEZ2018[4] nerve model. Data presented above set parameter `cihc` to 0.03 (1 = normal).

- While resulting nerve-level simulated envelope-following responses (above) generally agree with observed EFR amplitude reductions, more data and simulations are needed to evaluate how well model results match our spectral findings with regards to R_{PLV}.



Conclusions

Inner hair cell damage results in neural coding deficits present in Envelope Following Responses to stimuli with sharp modulations or fluctuations.

- The types of envelopes that most drastically elucidate these deficits include square/rectangular modulations and tone complexes.

- While these deficits may also be observed in cochlear synaptopathic animals and humans[5] particularly when using the sq25 profile), they are markedly less-severe.

- Researchers using reductions in EFR amplitudes, alterations in spectral characteristics, or waveform morphology to isolate cochlear synaptopathic should be wary of significant confounds due to IHC damage.

- Place-time coding of tone complexes as a function of harmonic rank may be slightly altered in the presence of either pathology, which may affect pitch perception[6].

- Reductions in IHC transduction slopes, although not significantly affecting threshold, may create important deficits in suprathreshold coding of complex sounds, **which may represent an additional form of peripherally-based hidden hearing loss, beyond cochlear synaptopathy.**

Acknowledgements:

We would like to thank the Purdue Interdisciplinary Training Program in Auditory Neuroscience (TPAN; 1T32DC016853), NIDCD F30DC020916 (A.S.), and NIDCD grants R01DC009838 (M.H.) and R01DC015989 (H.B.).

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