Cross-Species Investigations of Place and Time Coding of Pitch Using Envelope-Following Responses

Poster S142

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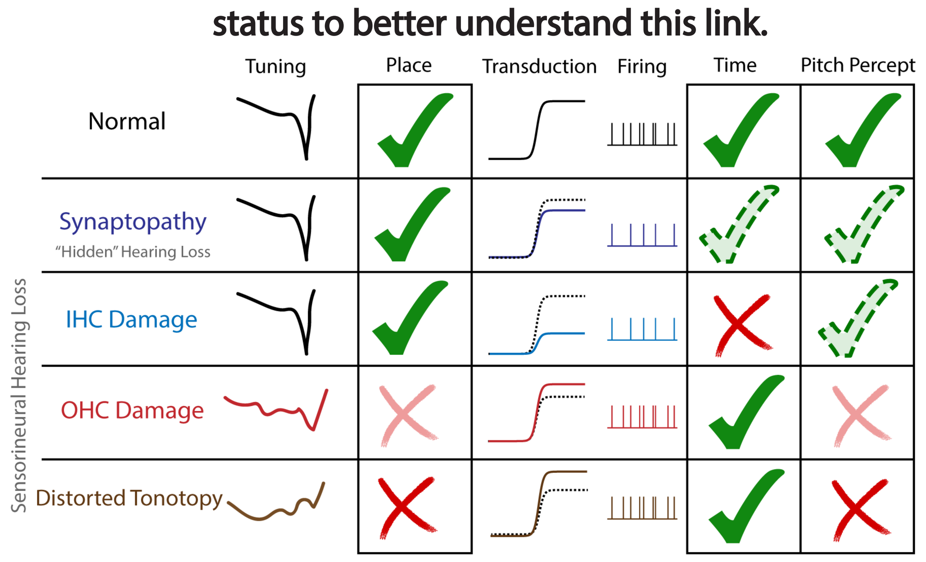
Introduction

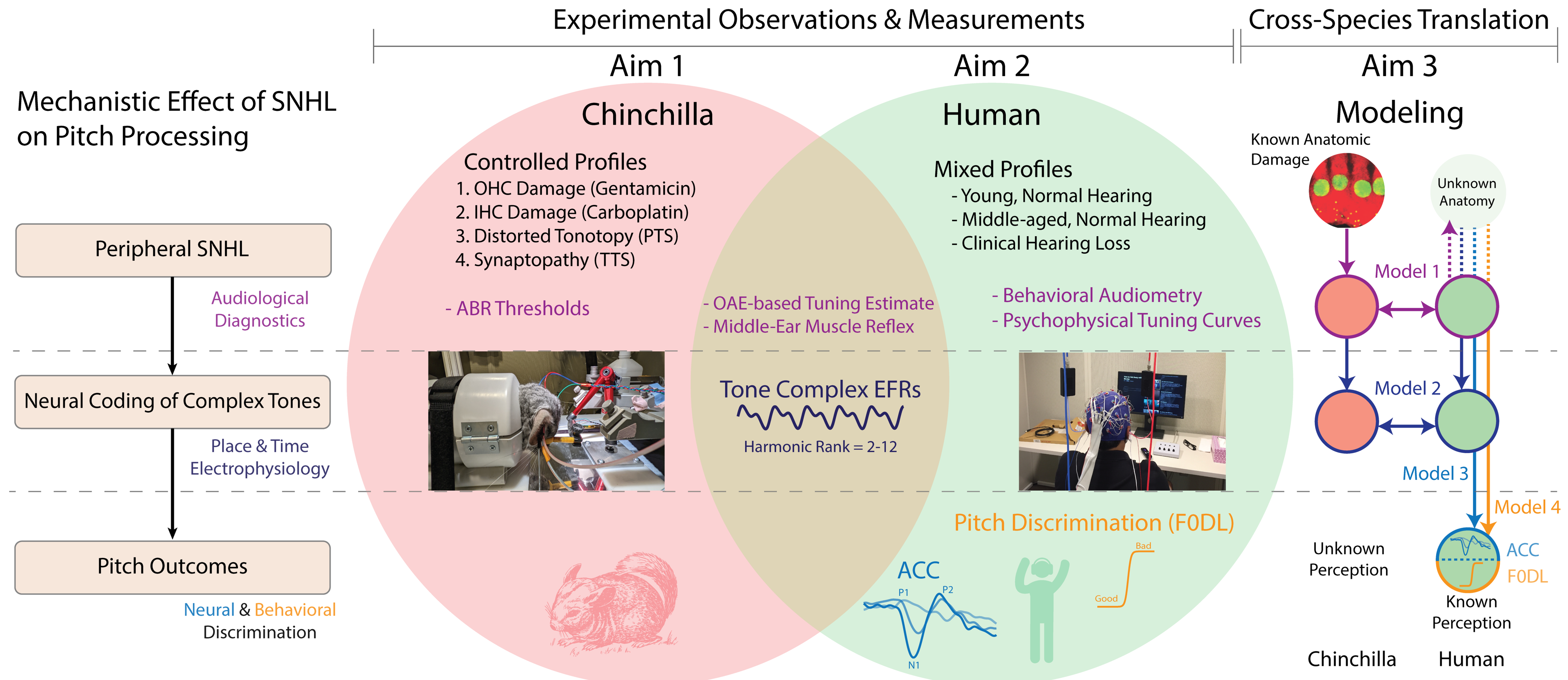
An elusive empirical neural explanation for pitch perception has sparked a multitude of cochlear place and time-dependent hypotheses.

- Longstanding pitch theories weigh the importance of **tonotopy** vs **temporal coding**
- **Our understanding of the impact of Sensorineural Hearing Loss (SNHL) on pitch perception and neural coding of tone complexes remains convoluted and complex**
- **Cochlear Synaptopathy, Inner Hair Cell** (IHC), and **Outer Hair Cell** (OHC) **damage** may differentially impact pitch perception, despite often being indifferentiable through non-specific standard clinical assays (i.e. Audiometry, Distortion Product Otoacoustic Emissions)
- **Band-limited tone complexes** are an useful stimuli for probing the fidelity of cochlear time and place cues through both physiological (Envelope Following Responses, EFRs) and behavioral (Fundamental Frequency Difference Limens, F0DLs) measures

Here, we describe the development of a novel cross-species study framework that leverages EFRs collected in animal models of hearing loss and human subjects with diverse hearing status to better understand this link.



Framework

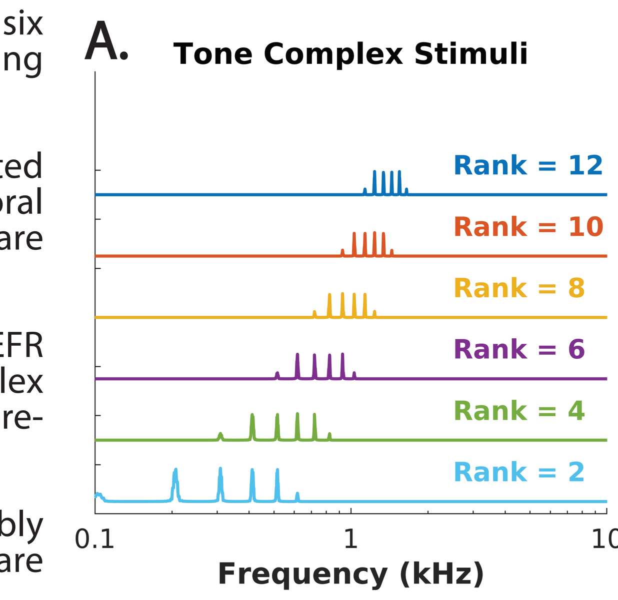


SNHL likely results in pitch perceptual deficits dependent on the anatomic profile of cochlear damage.

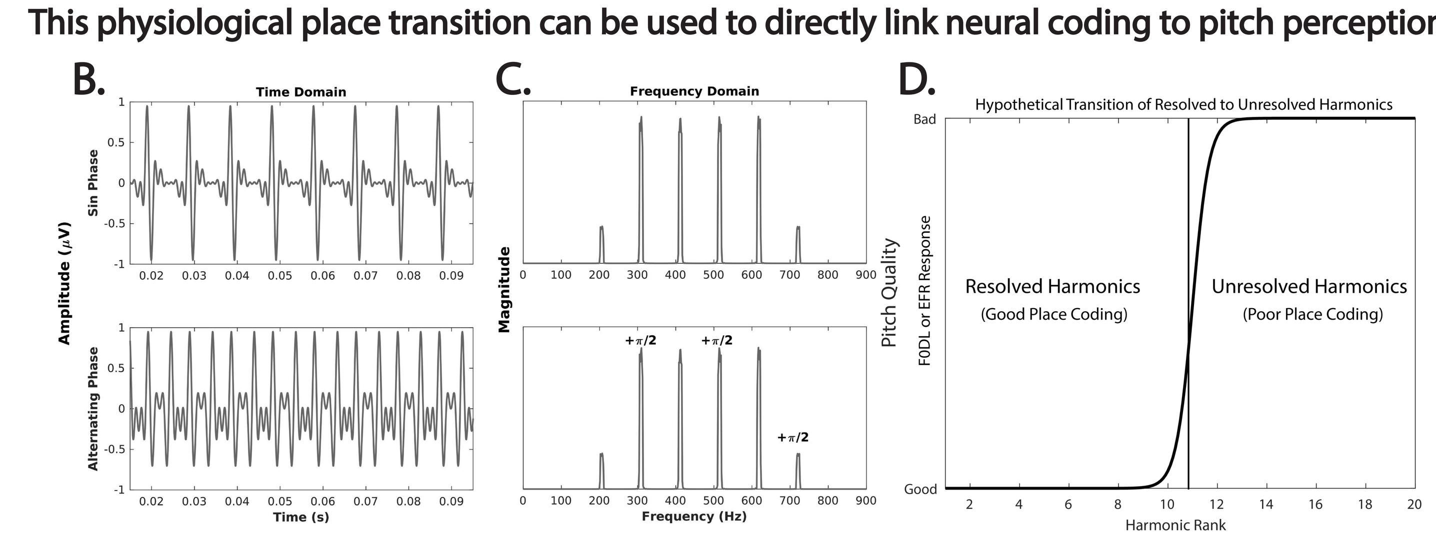
By utilizing EFRs to tone complex stimuli, controlled models of hearing loss in chinchillas[1] can be leveraged to better understand the mixed profiles of hearing loss that appear in a broad population of human subjects, providing a mechanistic explanation for the variability seen in pitch outcomes like Acoustic Change Complex (ACC), and F0DLs.

Stimuli

- To finely examine harmonic resolvability, EFRs to six stimuli were selected to investigate neural coding across cochlear place (A).
- The harmonics in each tone complex were presented in alternating (ALT) phase. This results in a temporal envelope modulation of 2*F0 (B), while place cues are spaced 1*F0 apart (C).
- **Physiology** (Human & Chinchilla): This elicits an EFR with periodicity F0 when all harmonics in the complex are resolved, but 2*F0 when harmonics are unresolved[2].
- **Perception** (Human): Additionally, F0DLs measurably increase (discrimination worsens) when harmonics are unresolved by the auditory system[3,4].



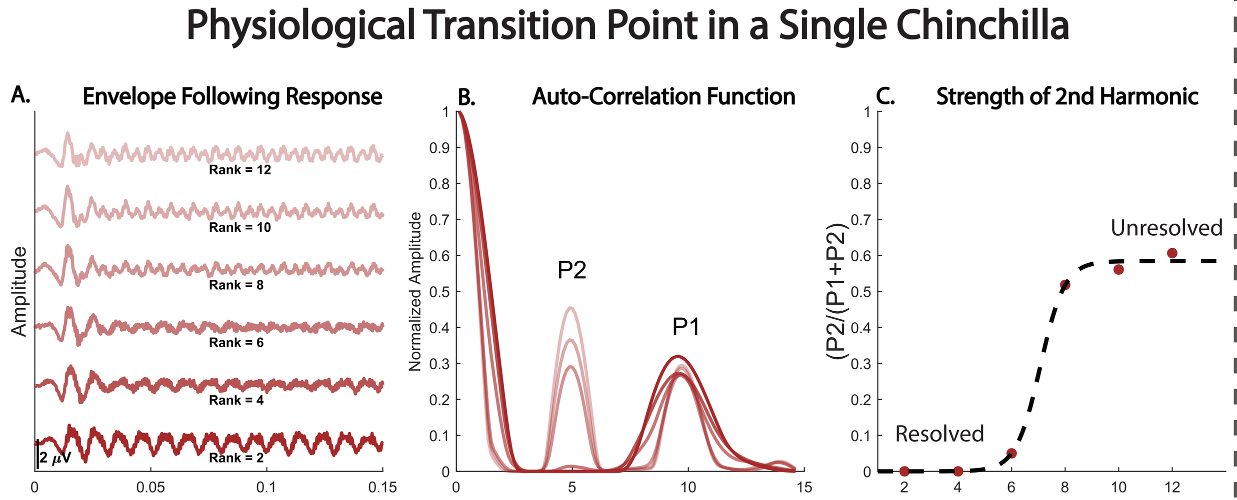
This physiological place transition can be used to directly link neural coding to pitch perception



Results

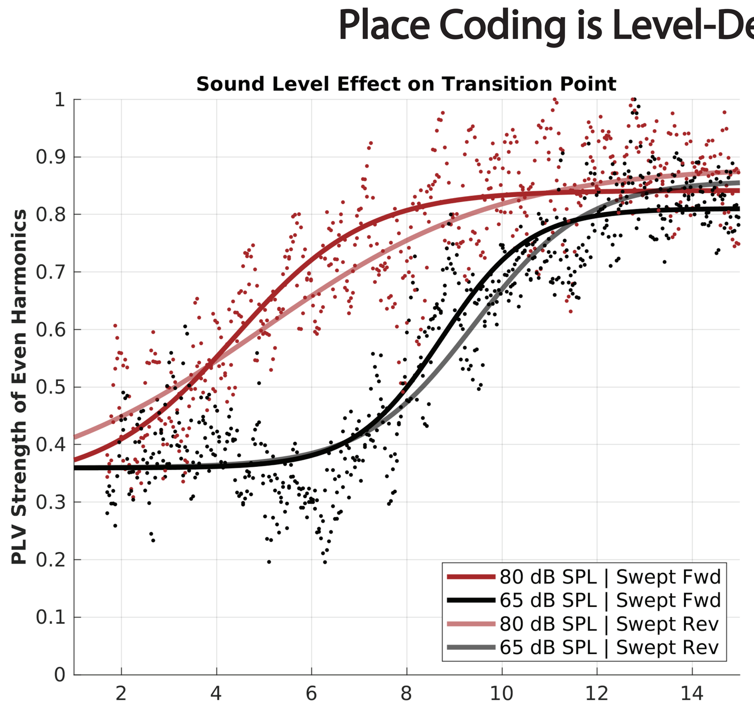
Chinchilla

Physiological Transition Point in a Single Chinchilla



EFRs to the described stimuli **demonstrate a resolved-unresolved transition, observable at the individual-subject level**. High SNR recordings are made possible through the use of anesthesia and a subdermal electrode montage.

Place Coding is Level-Dependent



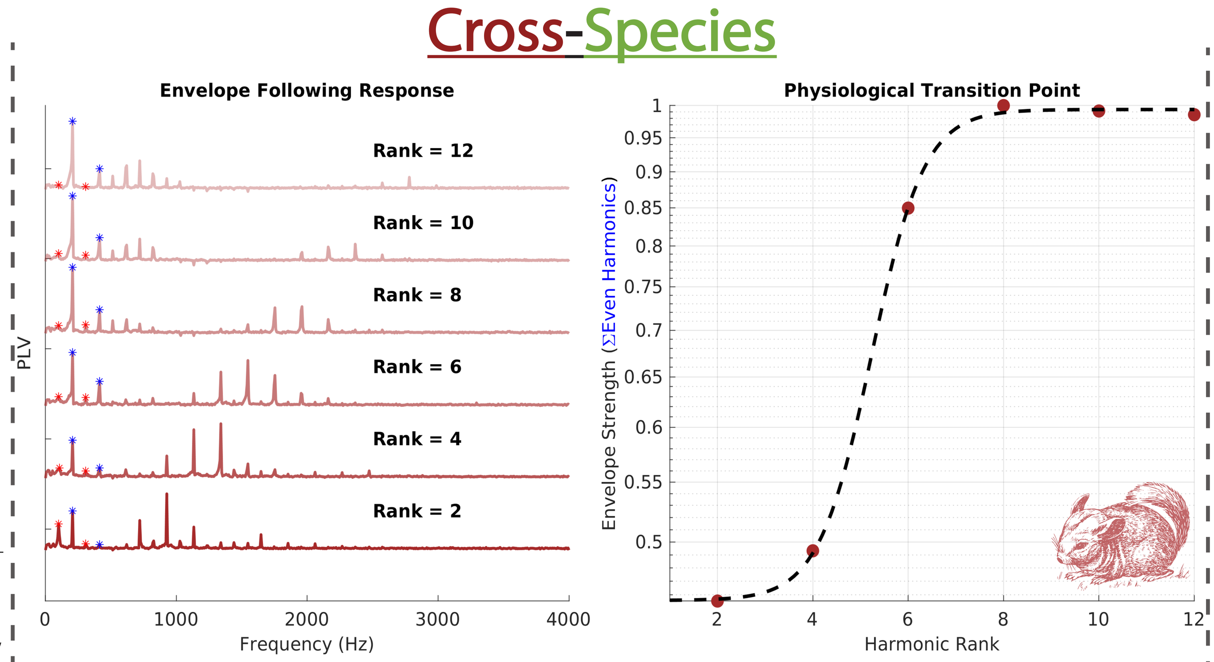
A stimulus swept in harmonic rank and PLV-based analysis were developed to explore this further.

Higher sound levels lead to more unresolved harmonics.

This results in stronger envelope coding at lower harmonic ranks, shifting the transition point in this measure left.

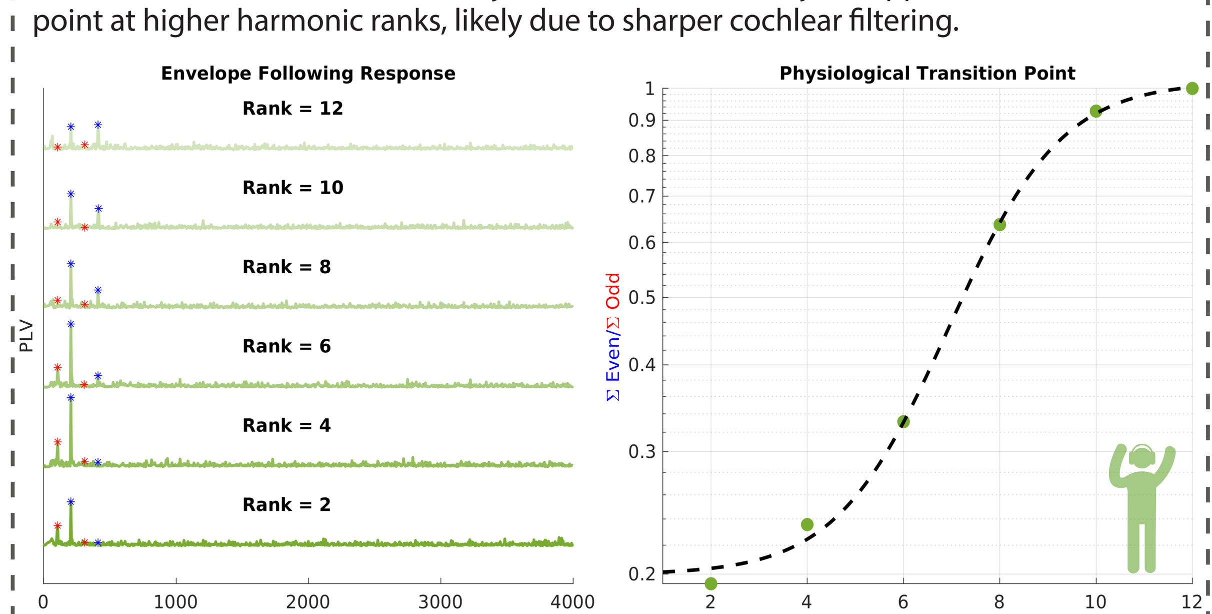
Chinchillas have broader tuning than humans and may have adapted to rely more strongly on temporal envelope cues for pitch discrimination[5].

Cross-Species

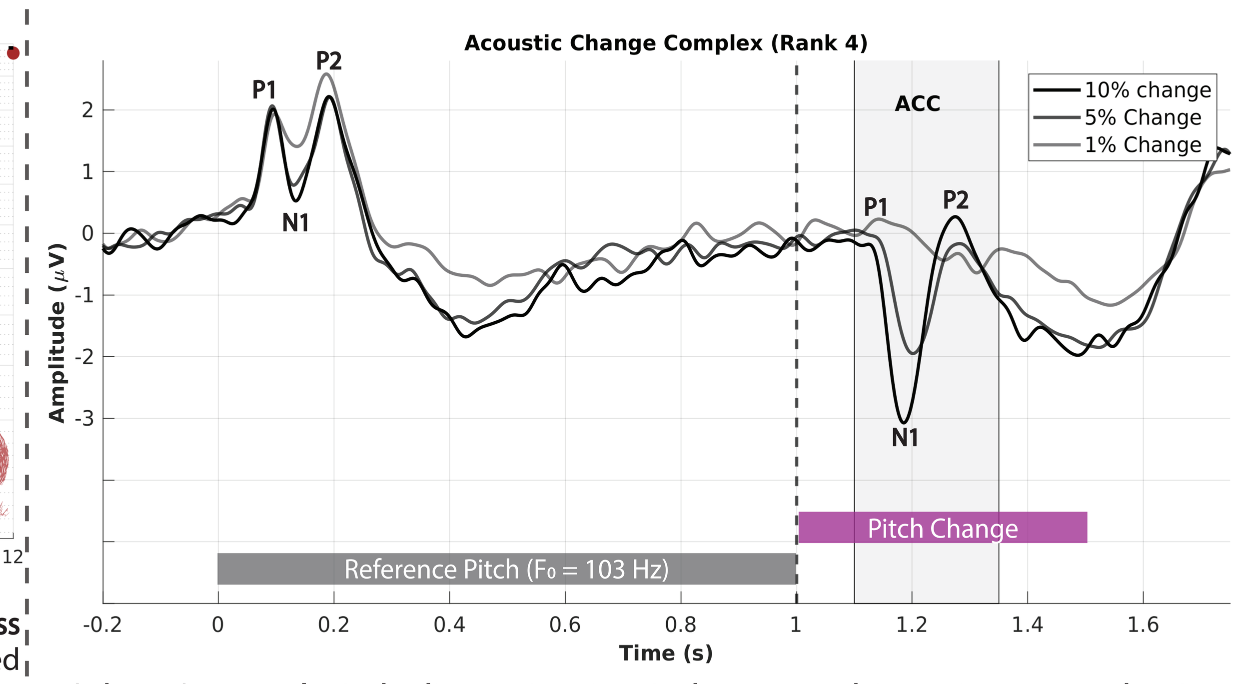


PLV-based spectral analyses were used to directly compare harmonic resolvability across species. The strength of the doubling in envelope periodicity (higher with unresolved harmonics) was quantified using energy in harmonics of 2*F0.

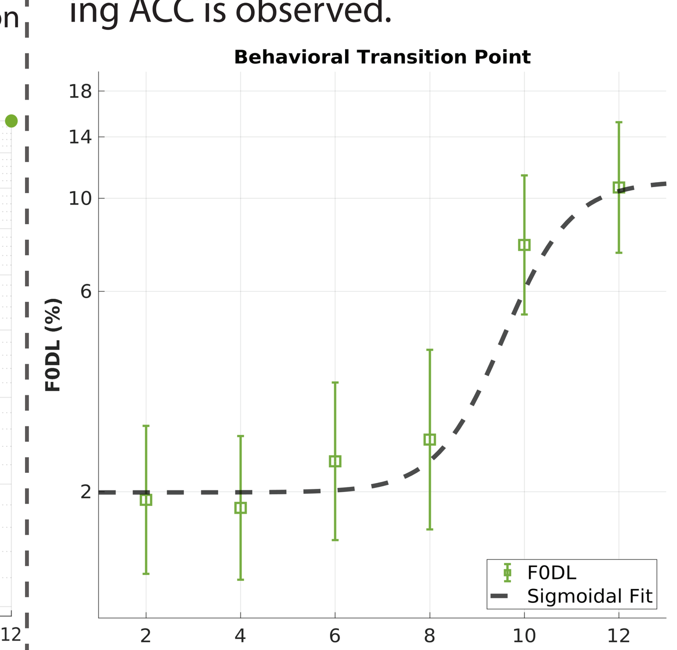
To achieve a clear transition point, stimuli were presented at 65 dB SPL in chinchillas (N=9), and 80 dB SPL in human subjects (N=9). Human subjects appear to have transition point at higher harmonic ranks, likely due to sharper cochlear filtering.



Human



(Above) Neural pitch discrimination in human subjects is assessed using the **Acoustic Change Complex**. With increasing pitch change, an increasing ACC is observed.



(Left) An **F0DL task** was developed to determine the **perceptual** transition point in pitch discrimination expected to correlate with resolvability.

This transition point occurs at a similar (though not exactly same) harmonic rank as the physiological transition point (middle panel).

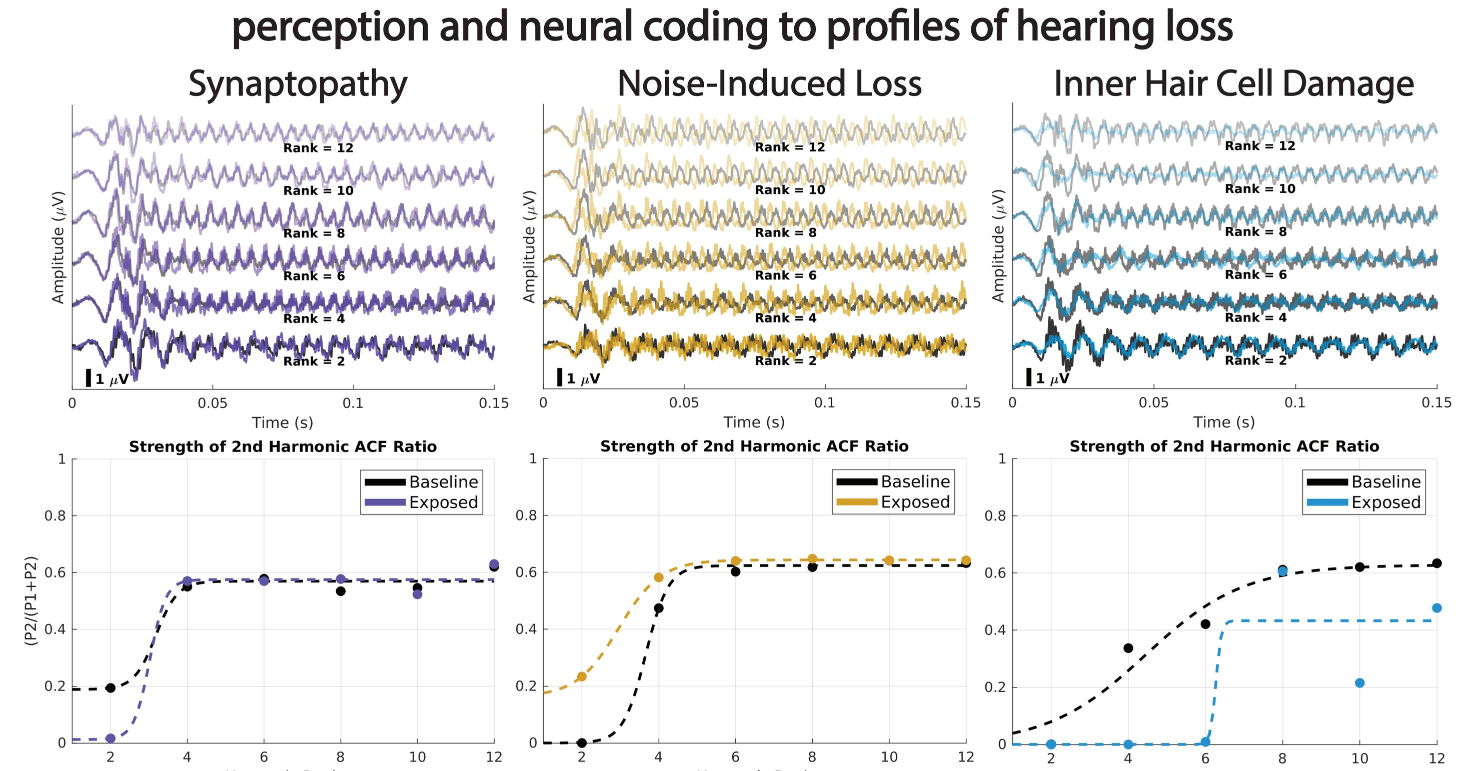
These assays of place coding and pitch perception are currently being tested on older subjects and those with hearing loss

Conclusions

Tone complexes as a function of harmonic rank serve as a useful stimulus set to probe the neural coding of pitch in humans and chinchillas

- Being able to assess pitch perception and its relevant neurophysiology in this described framework allows for a better link between psychoacoustic and physiological studies of pitch.
- Cross-species work is a powerful way to gain mechanistic insights to perceptual outcomes, however differences in cochlear filtering and anatomy should be properly considered.
  - Chinchillas have broader tuning than humans, leading to more unresolved harmonics at lower harmonic ranks, evident in the EFR-based transition point.
- This transition point is highly sensitive to sound level, especially in chinchillas.

This cross-species framework is being used to attribute variability in perception and neural coding to profiles of hearing loss



- Preliminary findings suggest substantial changes to the neural coding of tone complexes that vary based on type of hearing loss.
- Permanent Threshold Shifts likely result in broadened cochlear tuning, resulting in an earlier transition point, while Temporary Threshold Shifts do not appear to alter the transition point.
- IHC damage reduces the fidelity of high frequency envelope coding, shifting the transition point right, which could complicate the interpretation of this measure as purely a correlate of place coding.

Acknowledgements:

Data collection for this project was greatly assisted through ongoing collaborations with Samantha Hauser. We would also 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.) and Dr. Andrew Oxenham for helpful feedback and discussion related to this experimental approach.

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