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Efficient Encoding of Vocalizations in the Auditory Midbrain

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Overview

- Research goals
- Overview of the auditory system
- Encoding strategies
- Experimental design
- Experimental results and conclusions

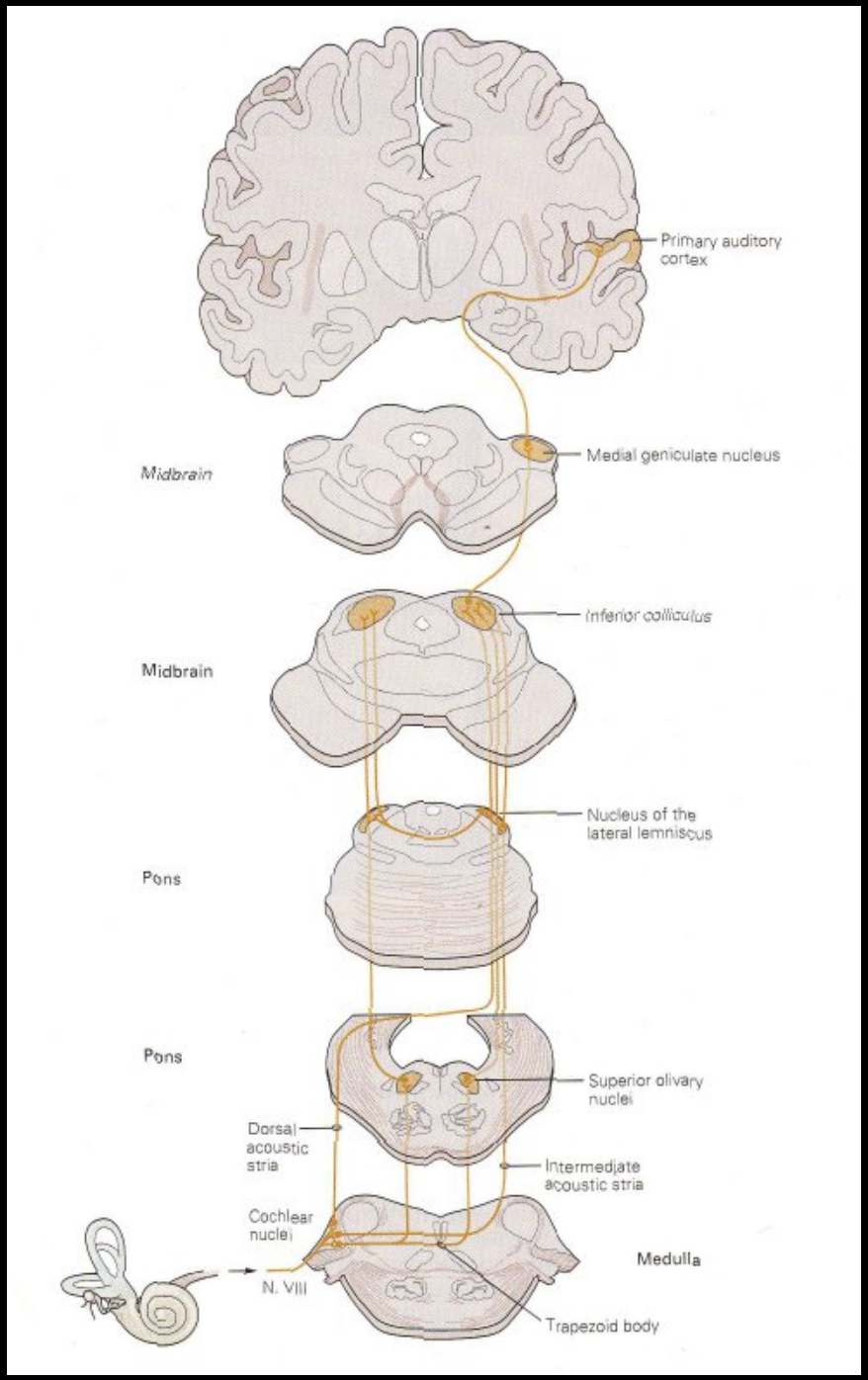
High Level Research Goal

- To gain a better understanding of how behaviorally relevant sound is processed by the auditory system
- And specifically…
  - How are vocalizations encoded by the Central Nucleus of the Inferior Colliculus (ICC)?
  - Does this provide evidence that the auditory system implements a progressive, “efficient” encoding of vocalizations?

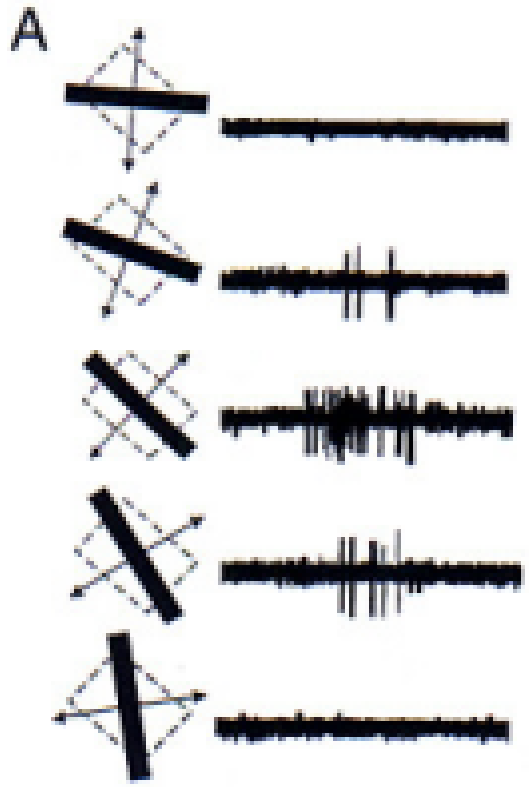
Ascending Auditory Pathways

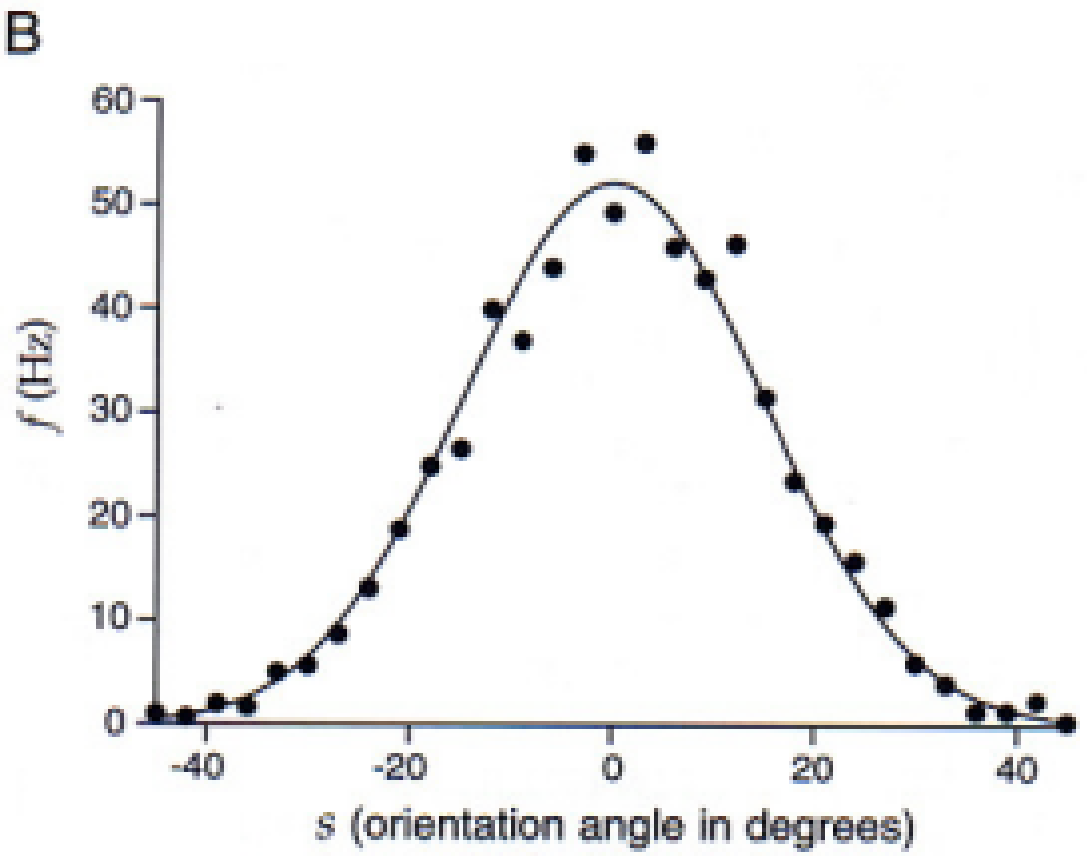
Cortical neurons are narrowly selective for complex stimuli

Peripheral neurons are broadly selective for simple stimuli

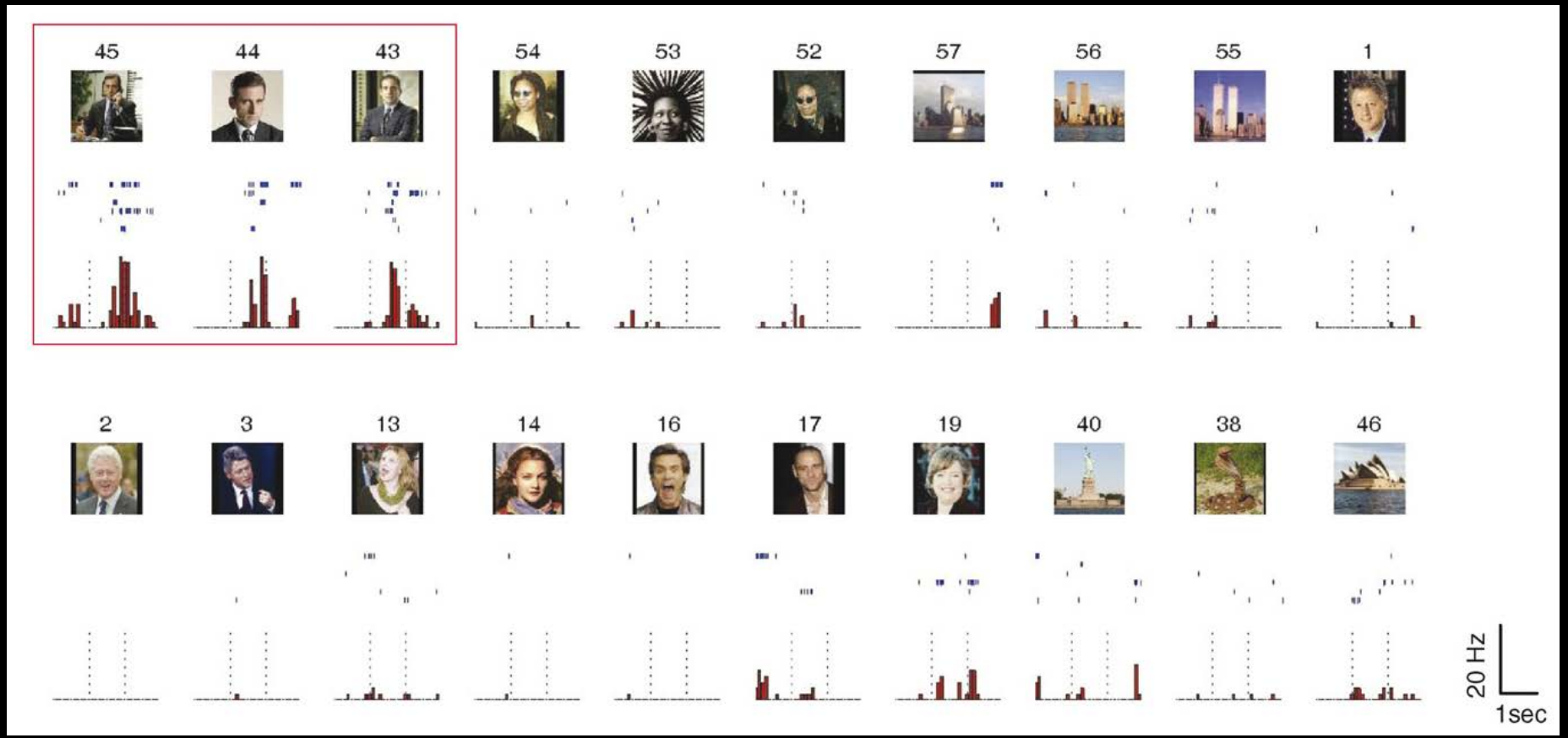


Selectivity at the Periphery of the Visual System



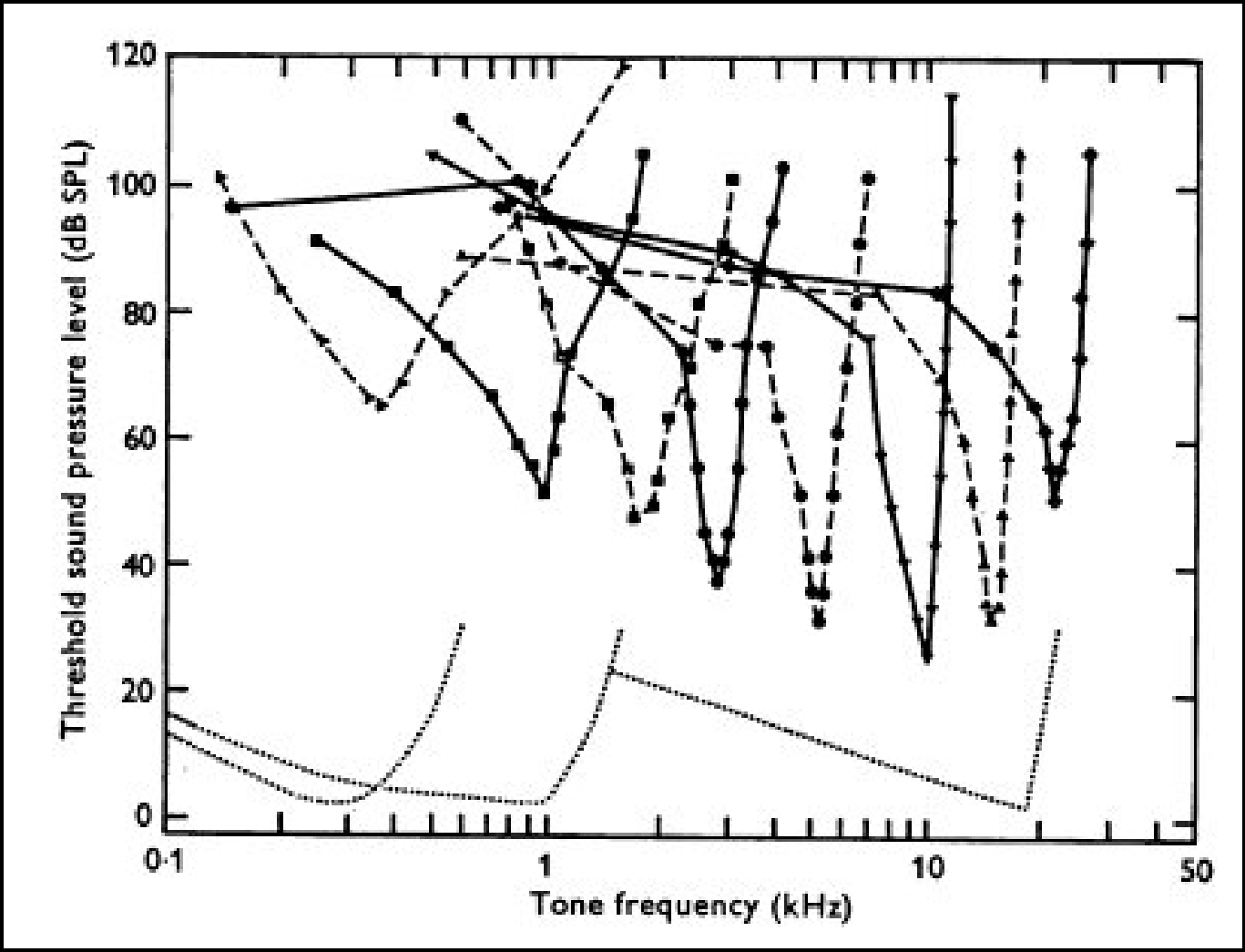


Increased Selectivity in the Visual Cortex



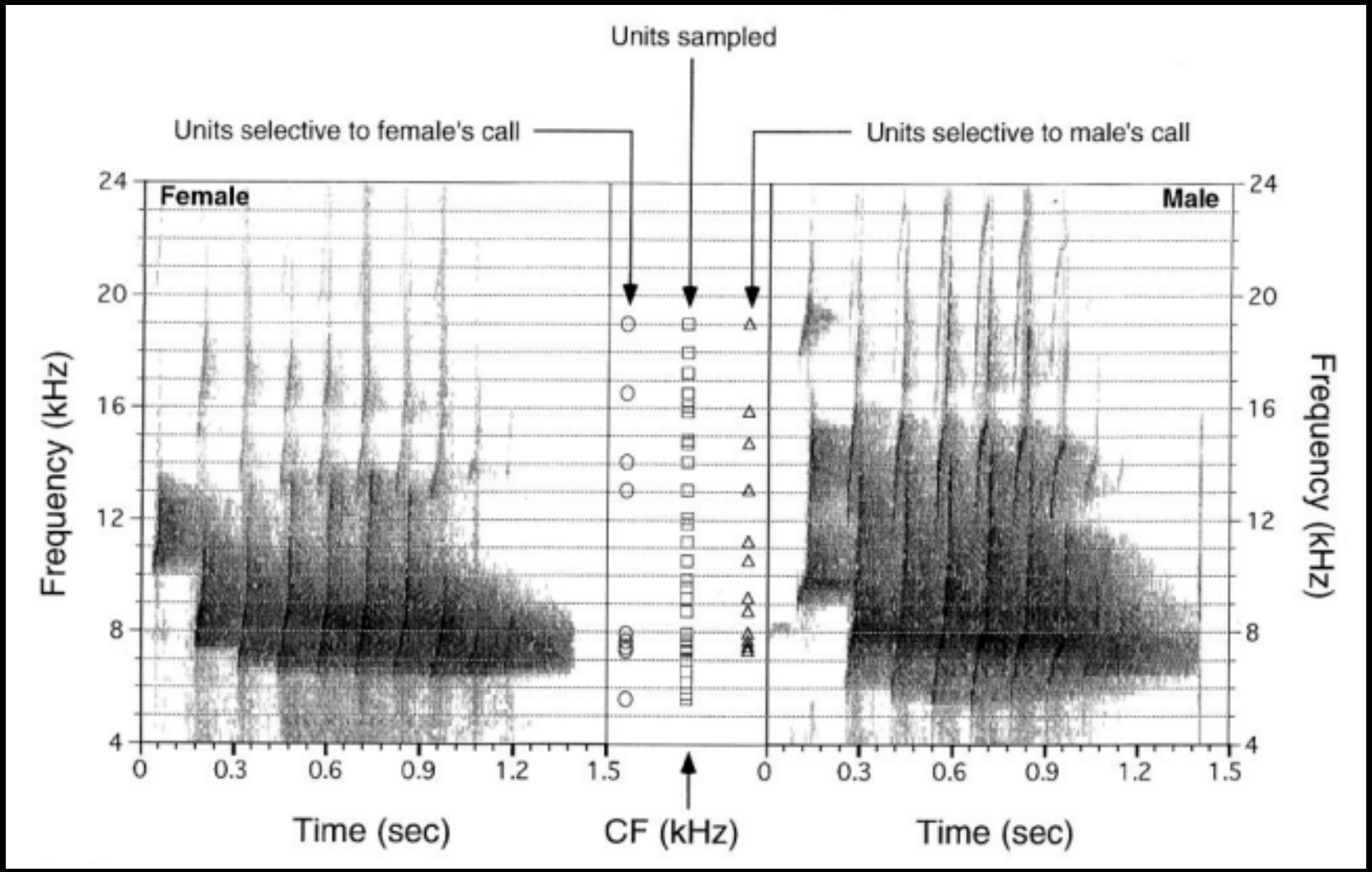
Quiroga, 2008

Auditory Nerve (AN) Responses Are Broad and Redundant



Katsuki, 1958

Selectivity for Vocalizations in the Auditory Cortex



Wang, 1995

Efficient Encoding in the Auditory Midbrain

- Is the encoding of vocalizations in the ICC more efficient than at the periphery?
- If so, is this due to increased
  - Selectivity? → Sparse Encoding
  - Sensitivity? → Distributed Encoding
- How do we test these hypotheses?

Stimulus Design

- We want to look for
  - Selectivity among vocalizations
  - Selectivity within vocalizations
  - Sensitivity to perturbations in vocalizations
  - Heterogeneity of individual and population responses
  - Efficiency of the encoding relative to the periphery

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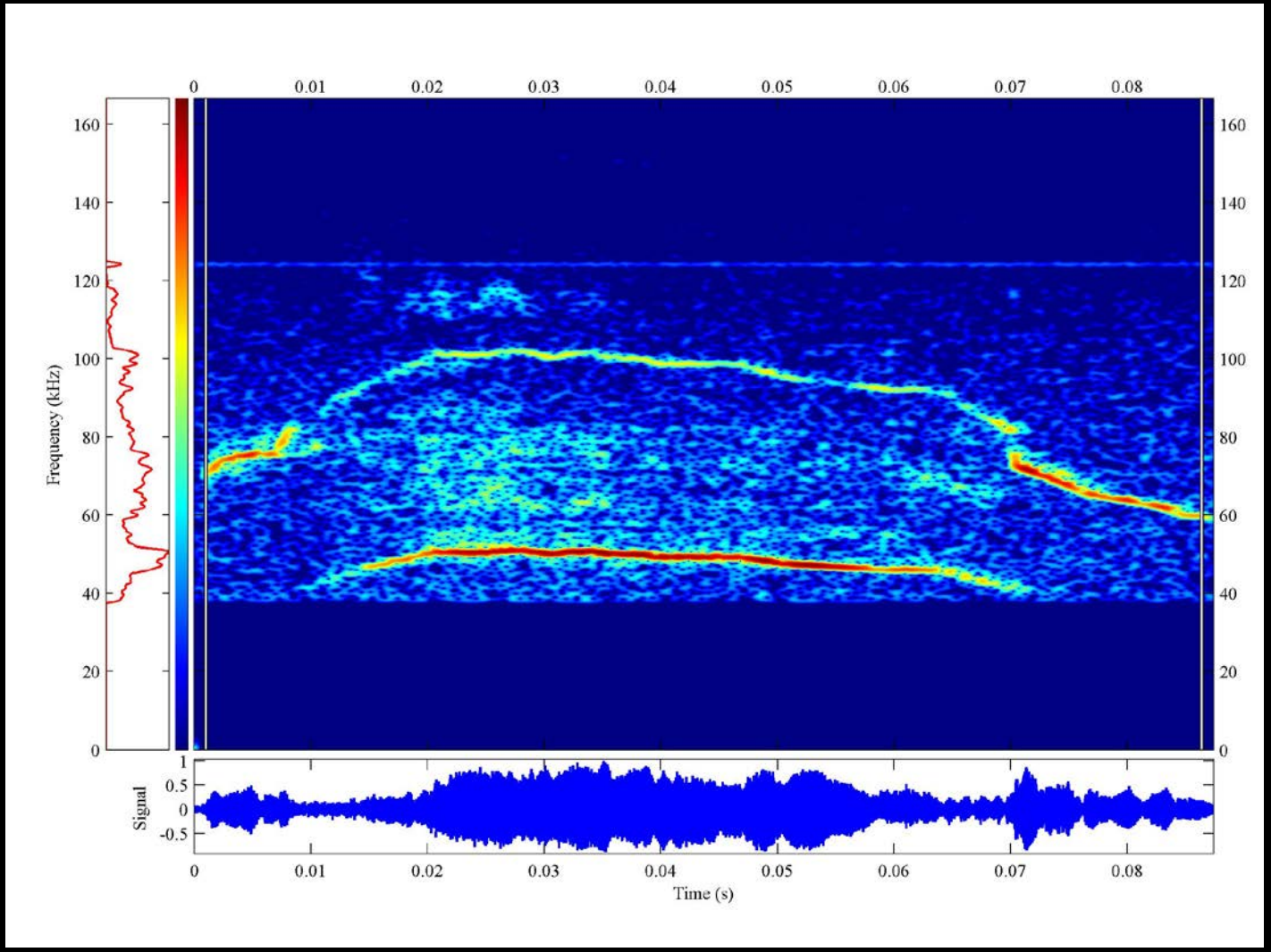
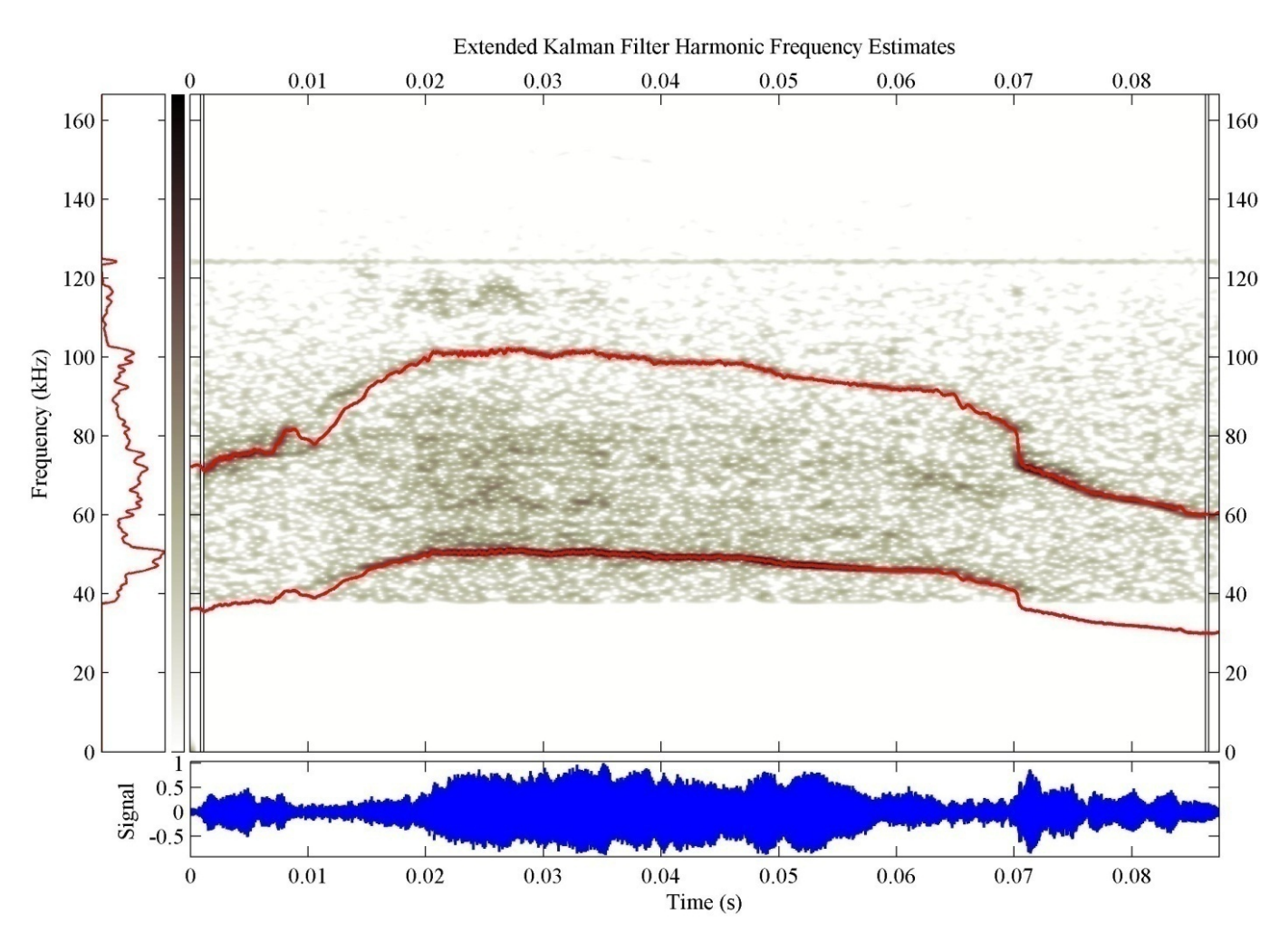
Methodological Contributions

- State space analysis and synthesis of vocalizations to aid in stimulus design
- Comparison of neural responses from both a spike rate and spike timing perspective
- Improved methods for creating input->output models of individual neurons provided the pure tone responses of these neurons
  - Used to approximate the responses of peripheral neurons

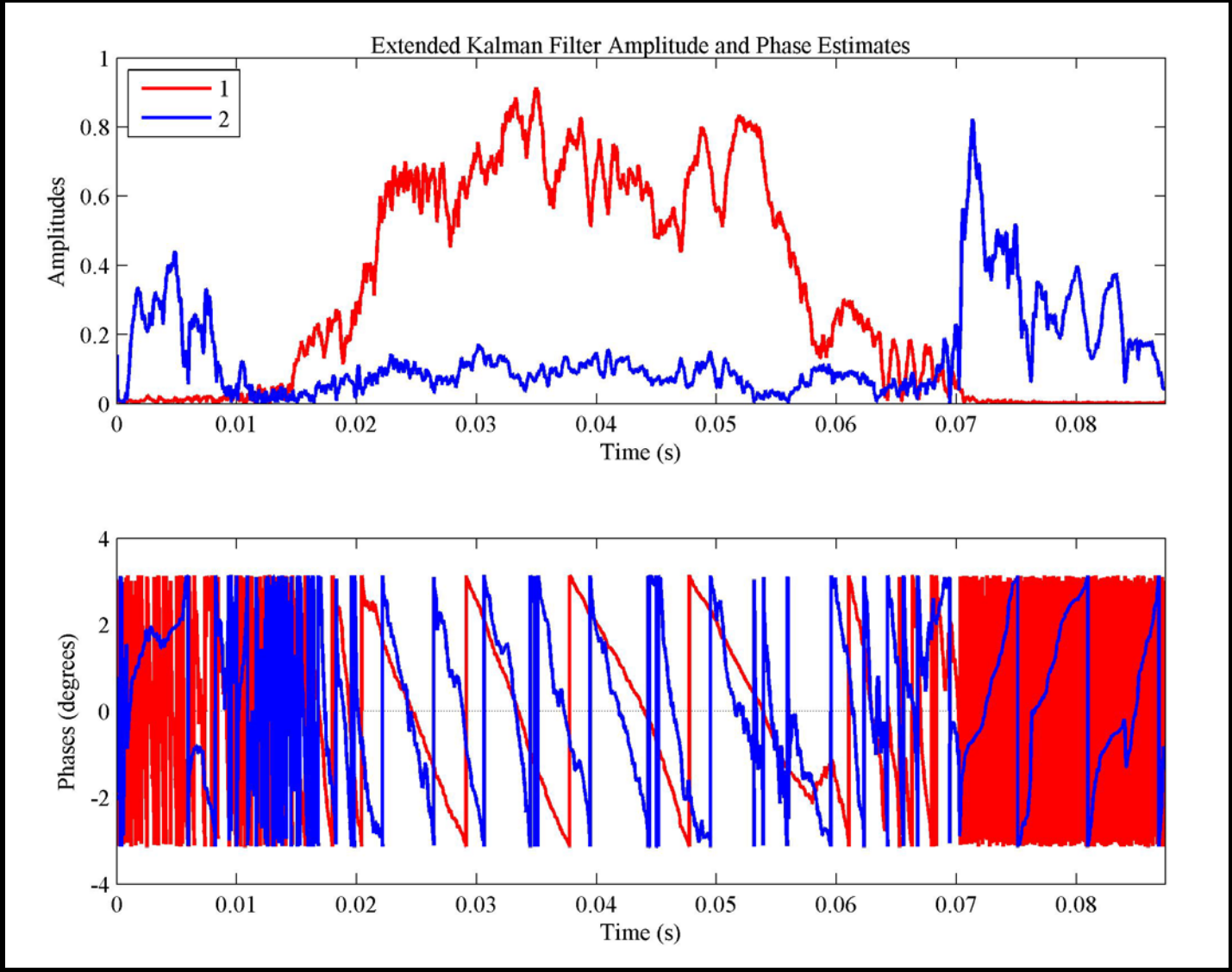
State Space Stimulus Design



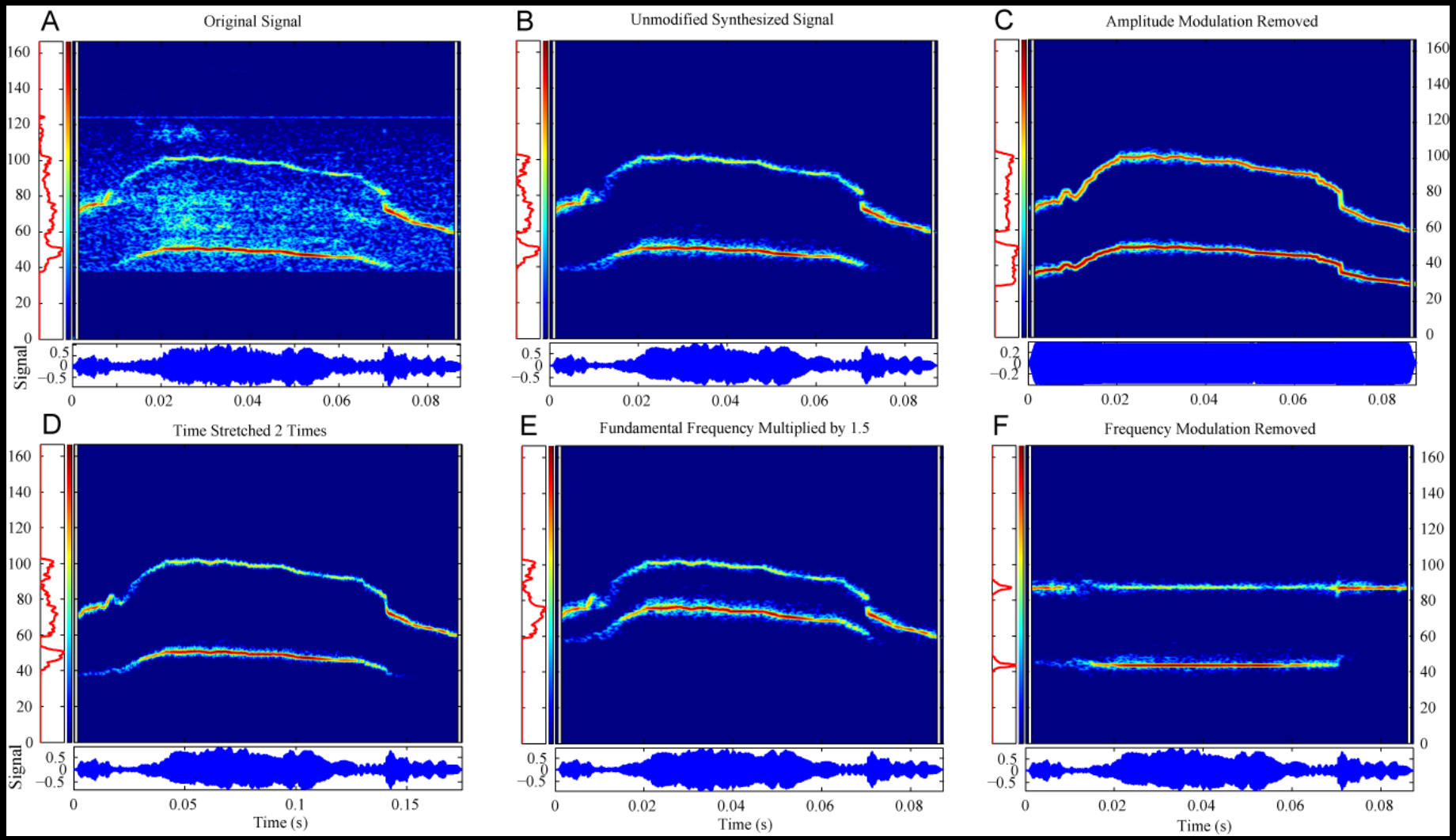
Frequency Tracking



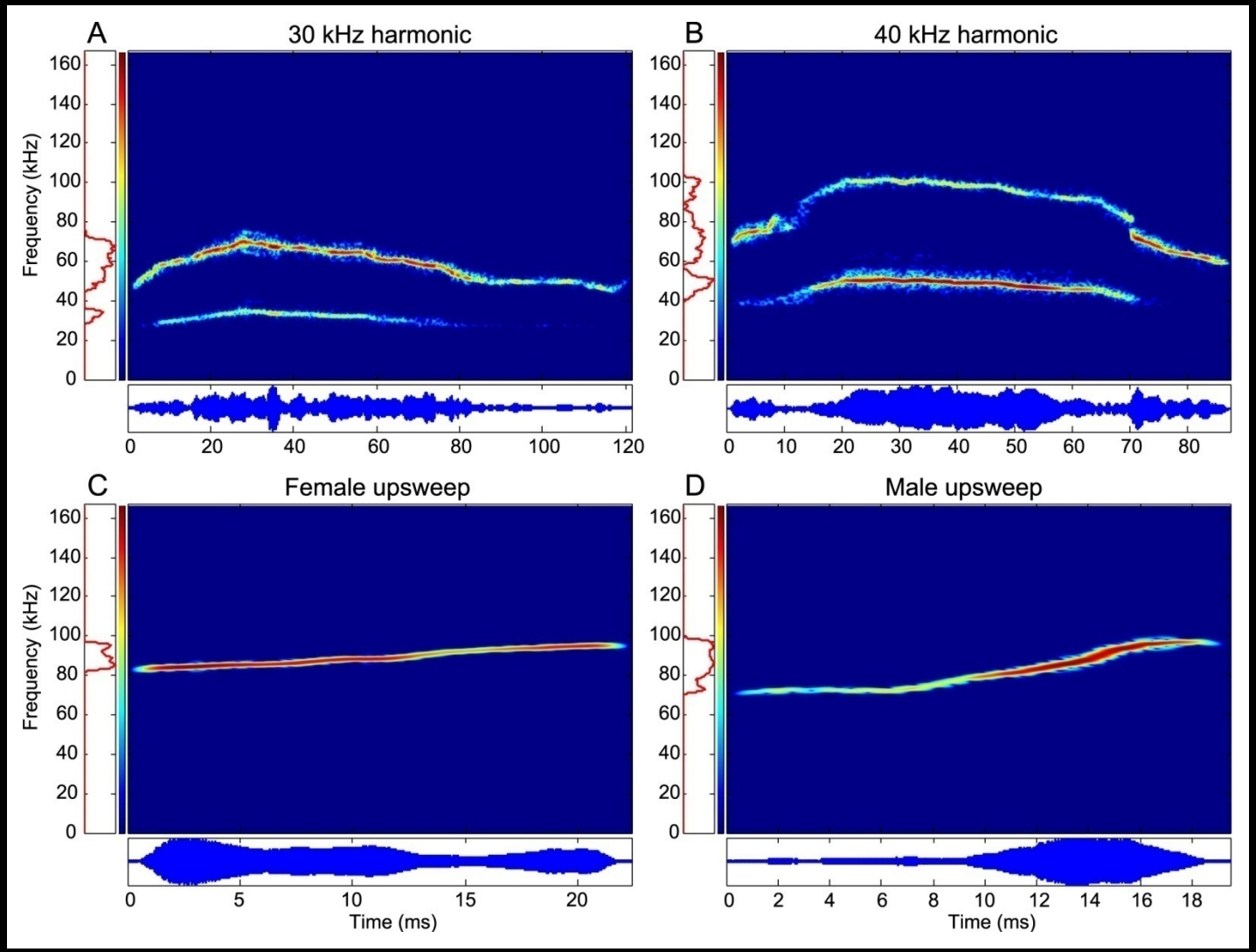
Amplitude and Phase Tracking



Perturbing a Vocalization



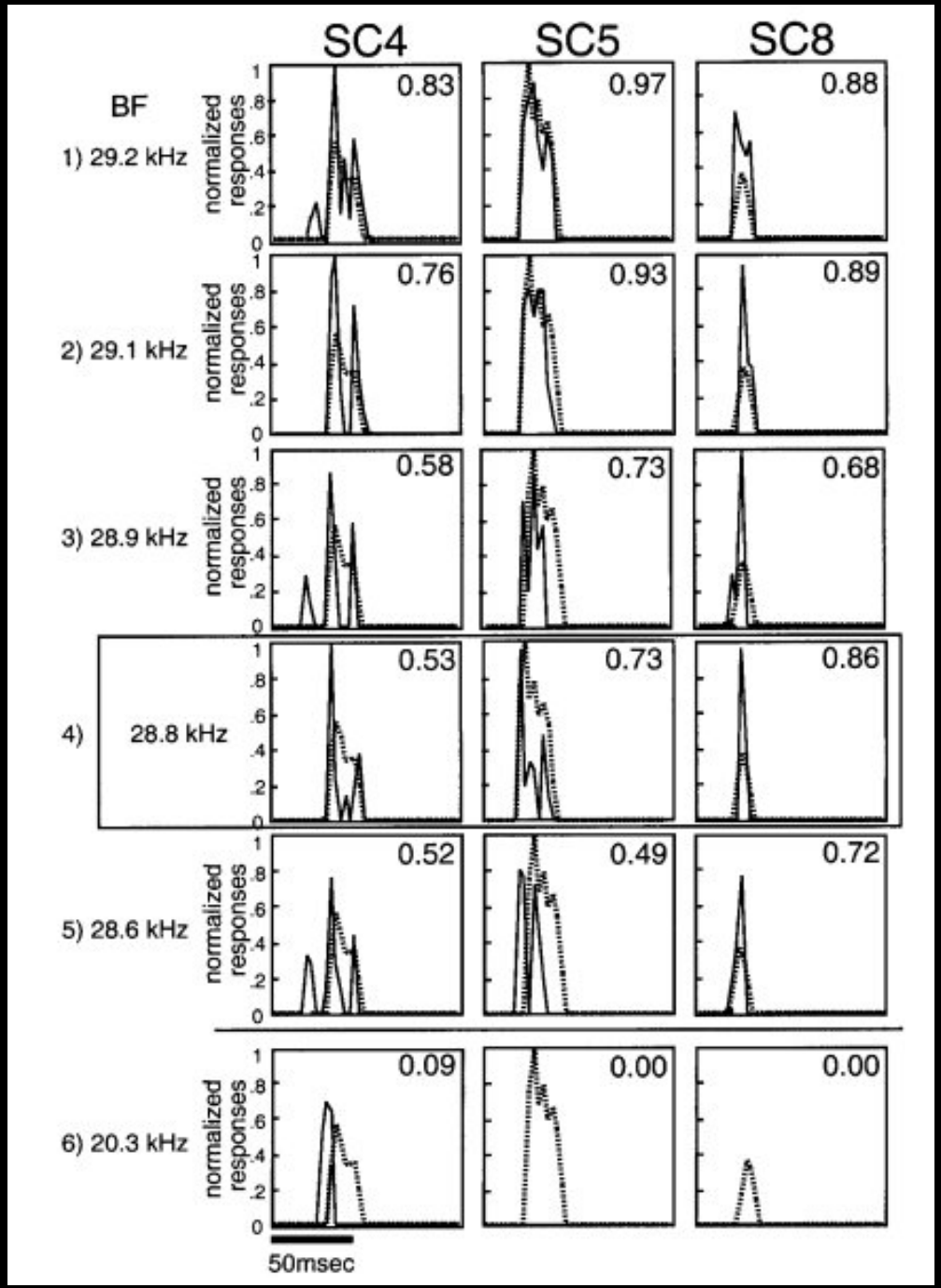
Base Vocalizations Used to Probe The Mouse Auditory System



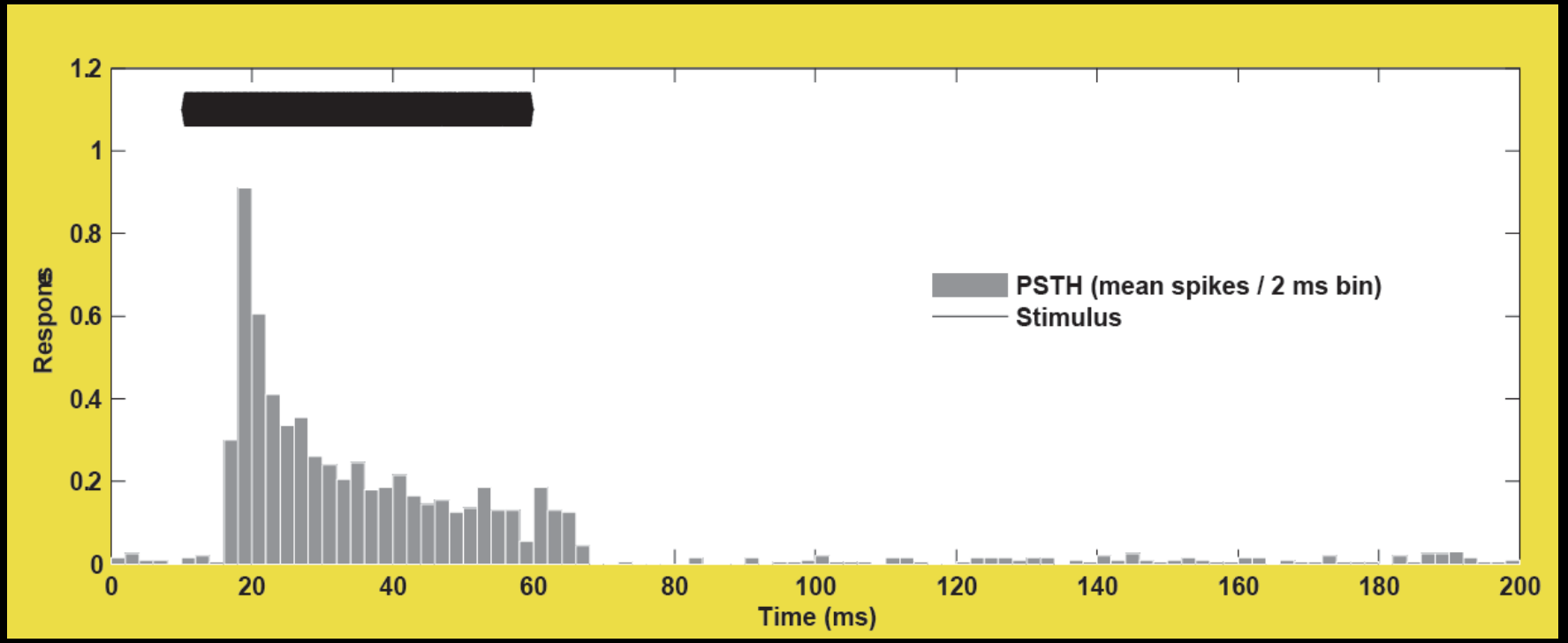
Modeling Peripheral Responses

- Previous results have shown that peripheral responses to arbitrary stimuli can be predicted by their pure tone responses

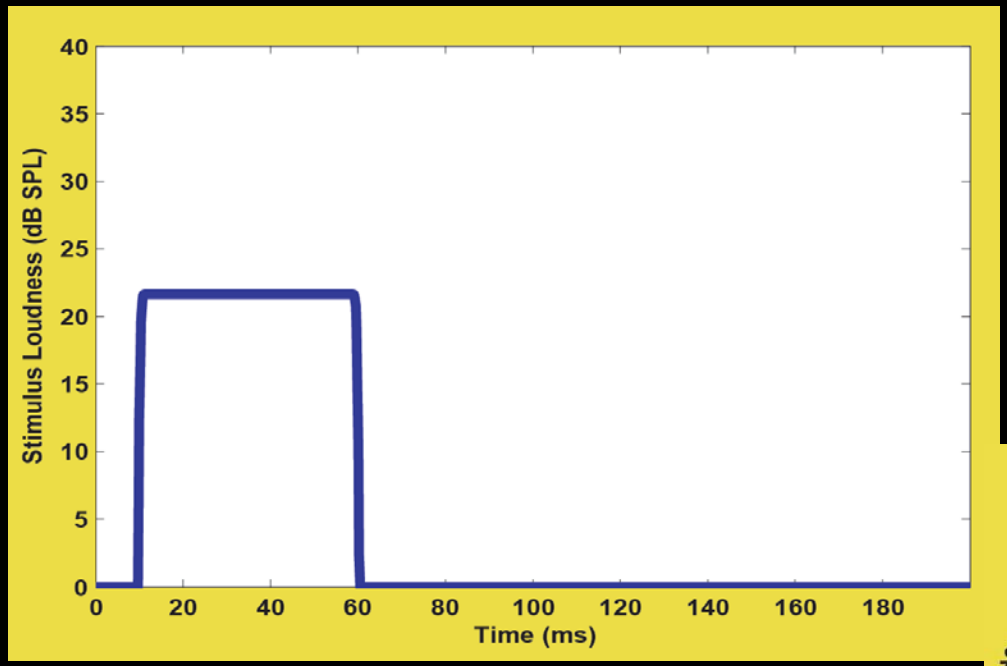
Bauer, 2002



Desired Response of the Model for a Single Pure Tone

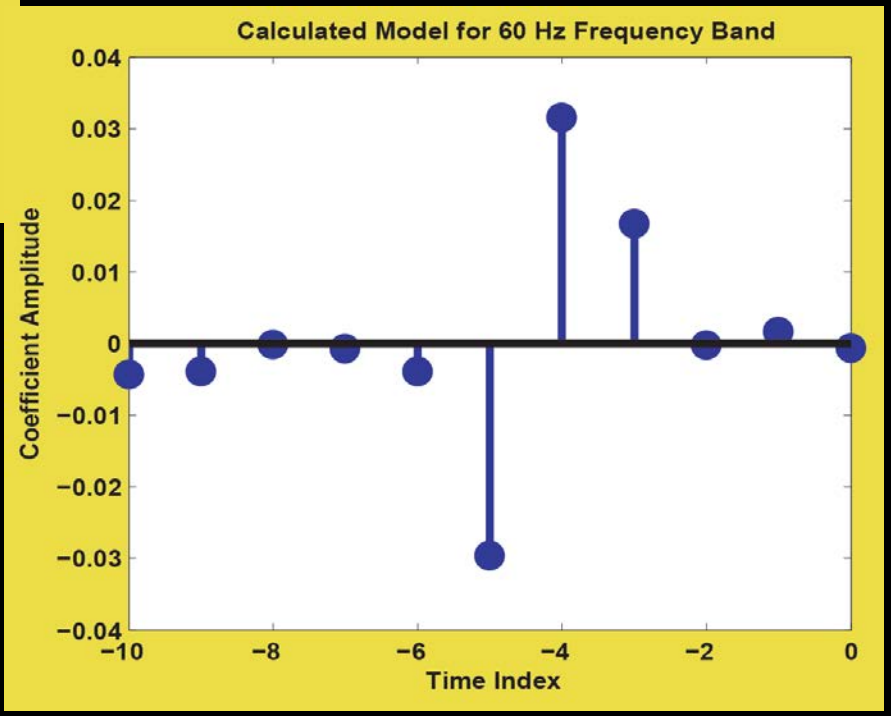


Modeling the Response to a Pure Tone

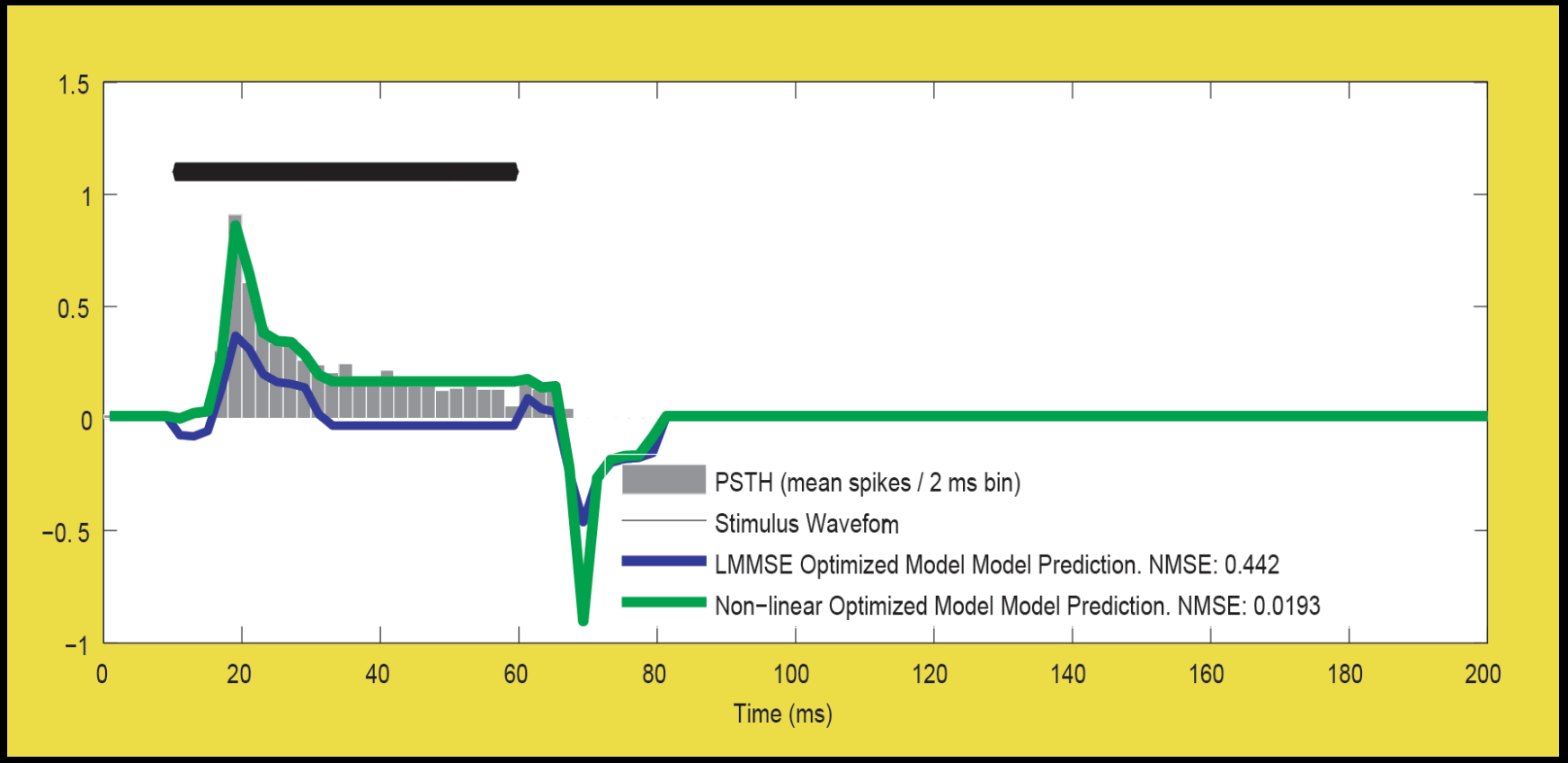


- Power of pure tone stimulus in the 60 kHz band

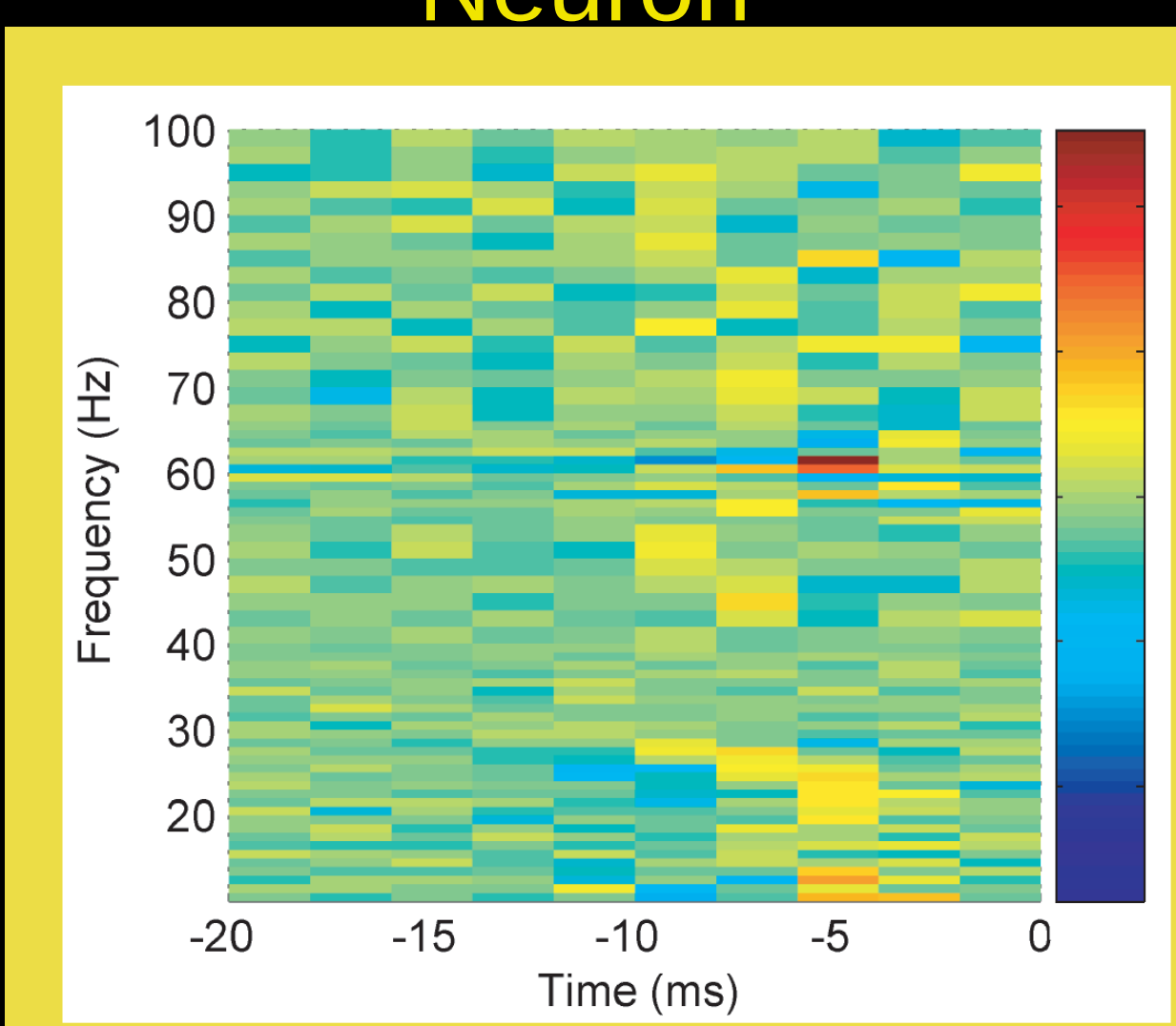
- The model has an independent input channel for each frequency present in the input stimulus
- Below are the coefficients of an FIR filter for the 60 kHz band of the model



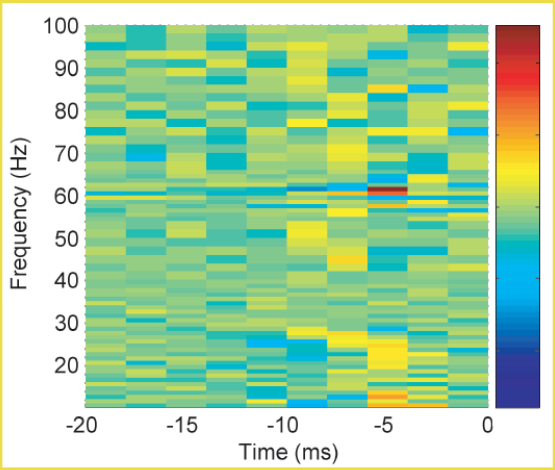
Fitting The Model

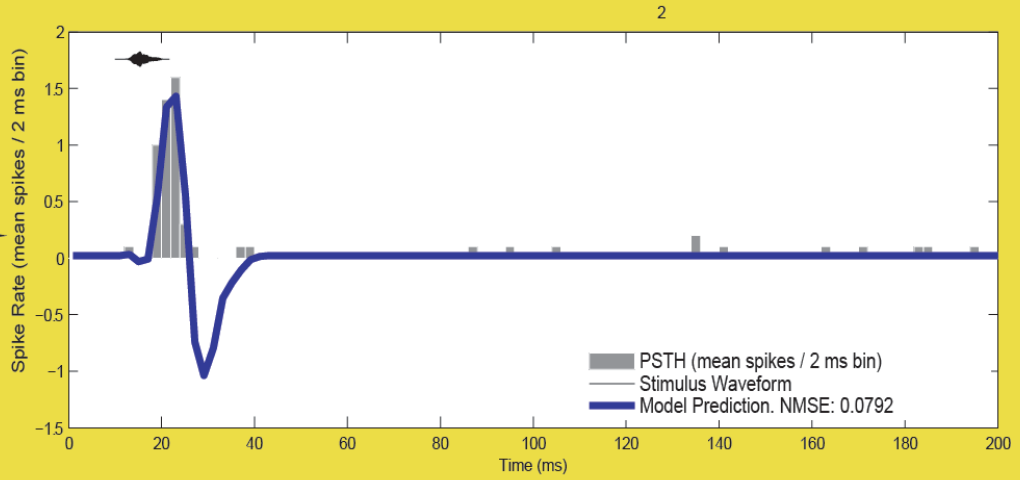


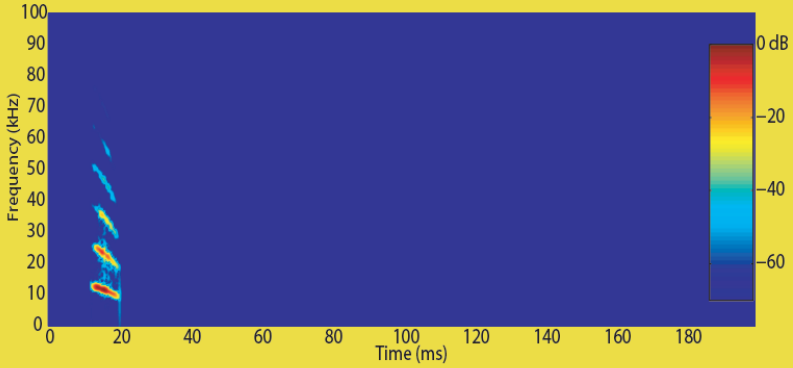
Model Parameters for a Single Neuron

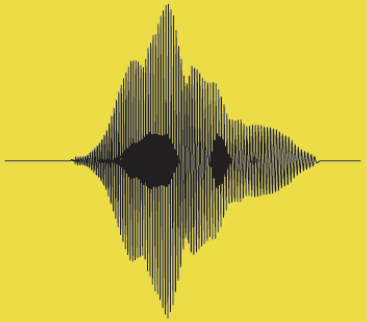


Predicting the Responses to Social Vocalizations

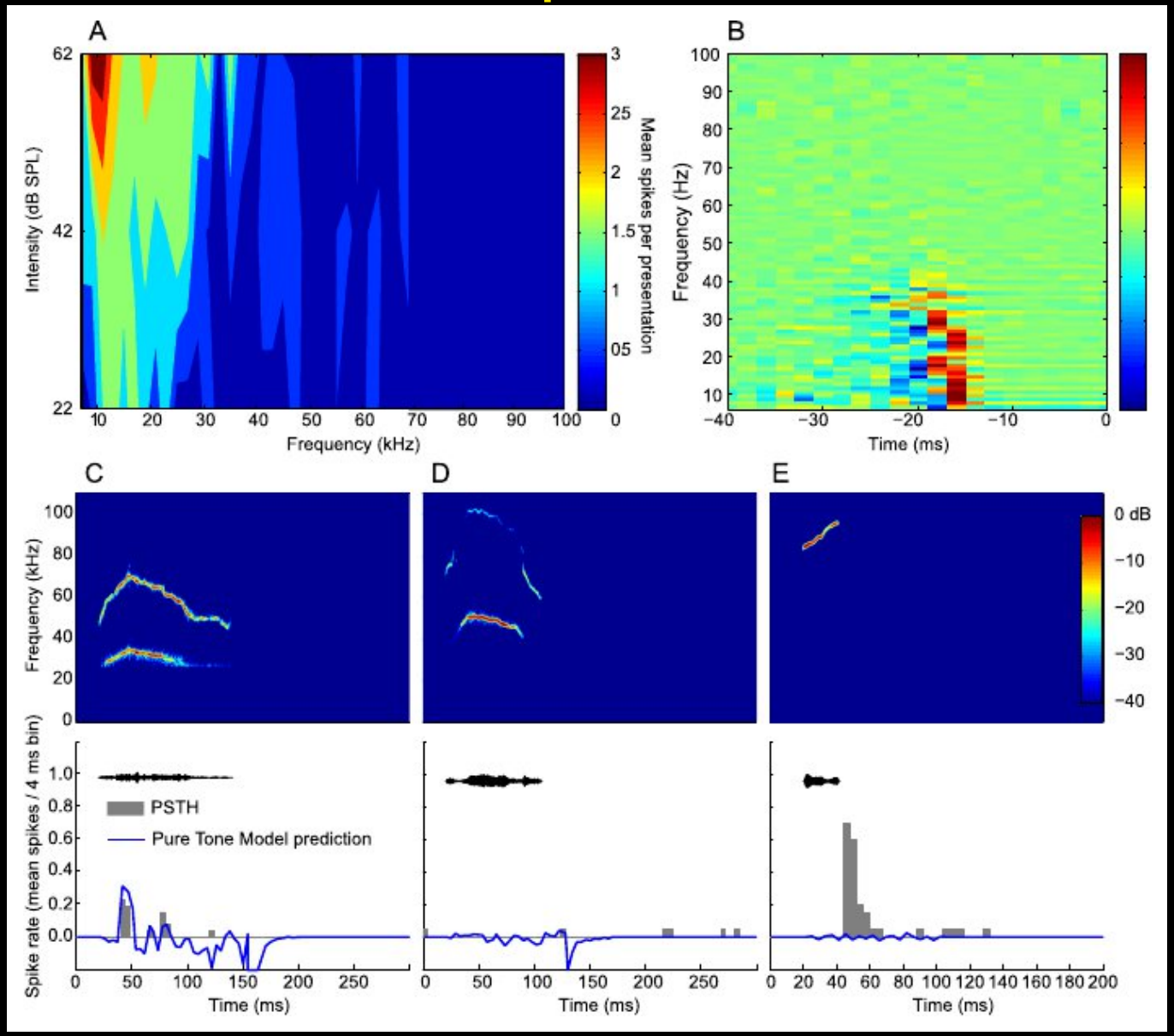




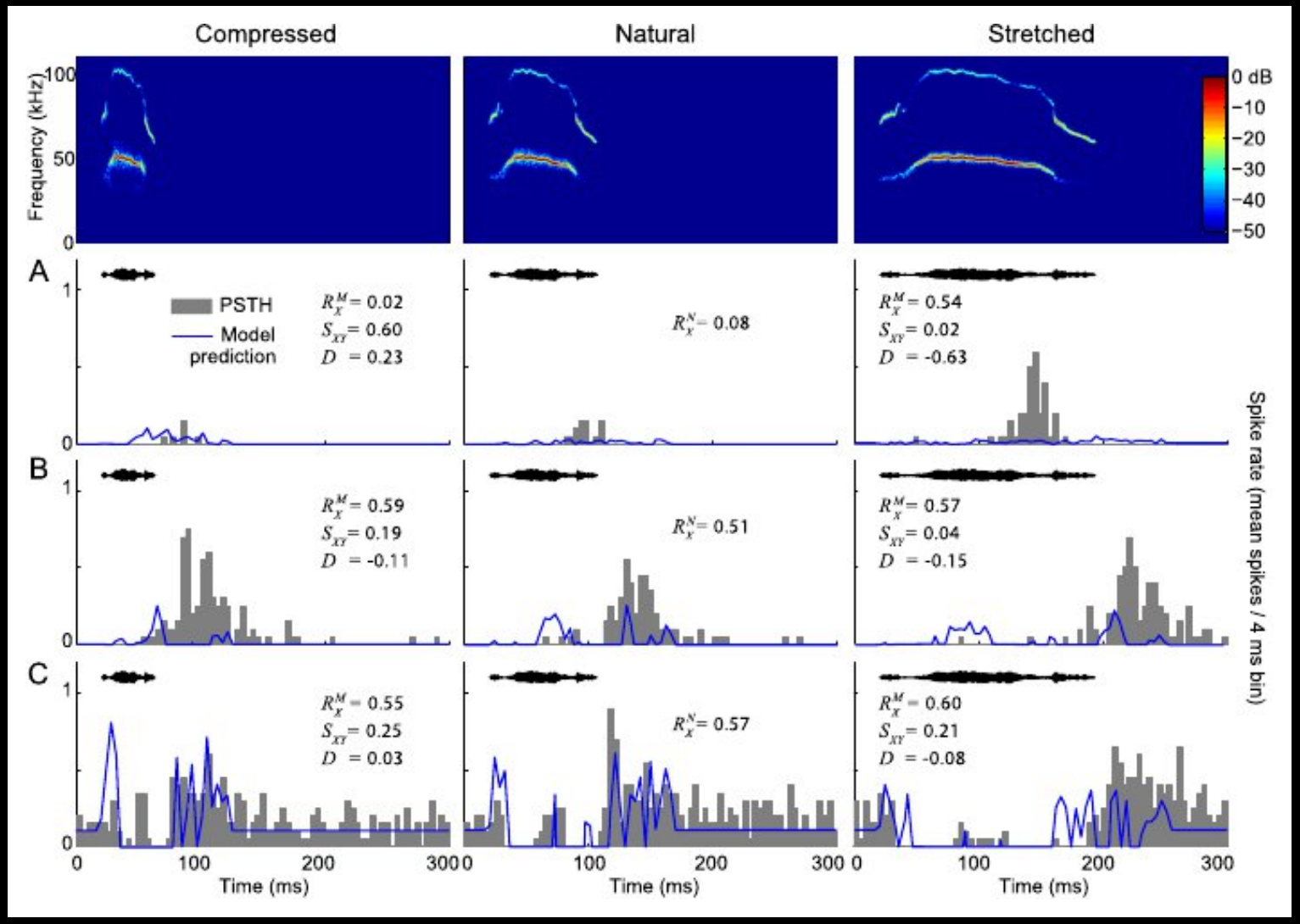




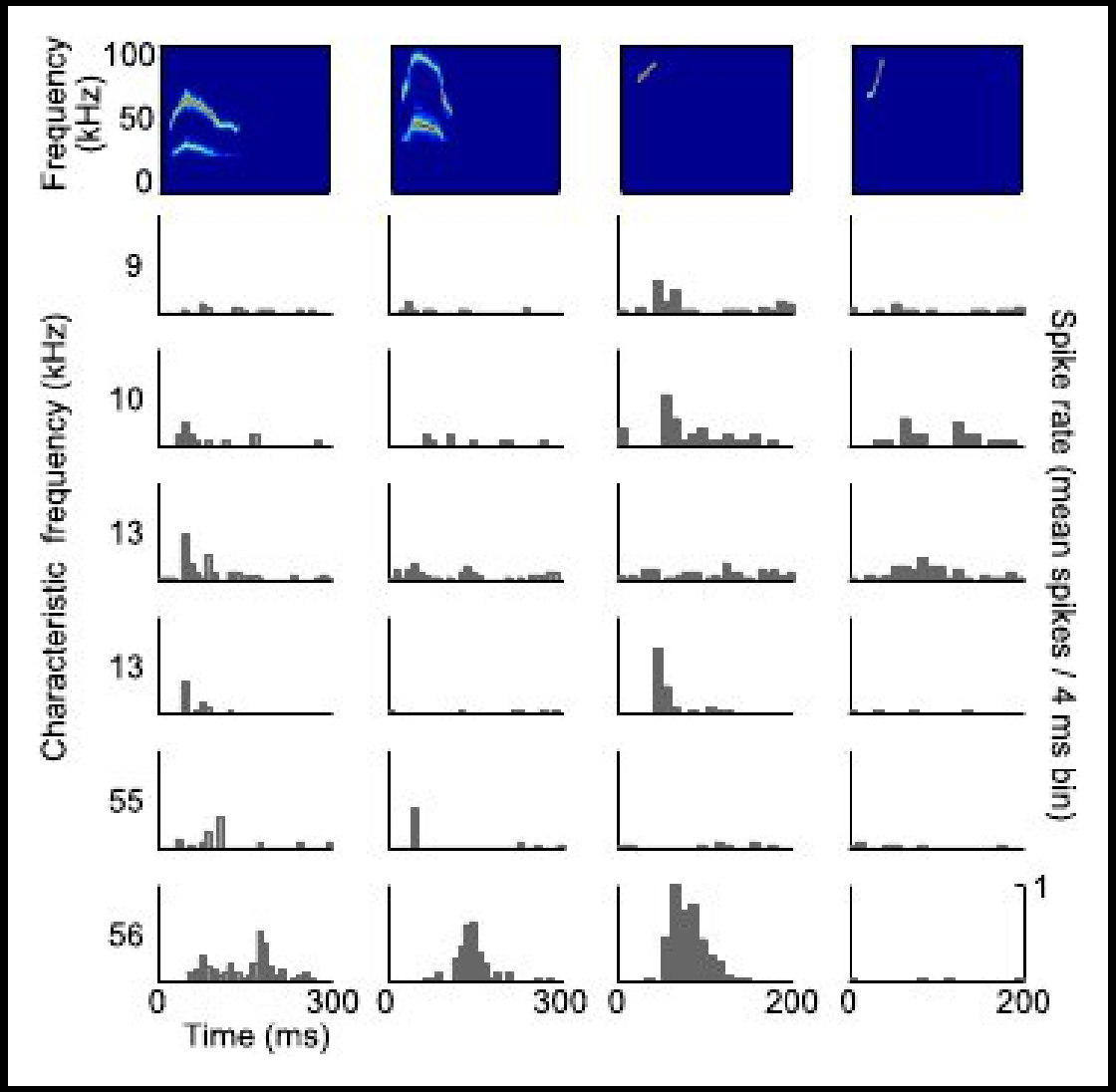
Comparing Recorded and Predicted Responses



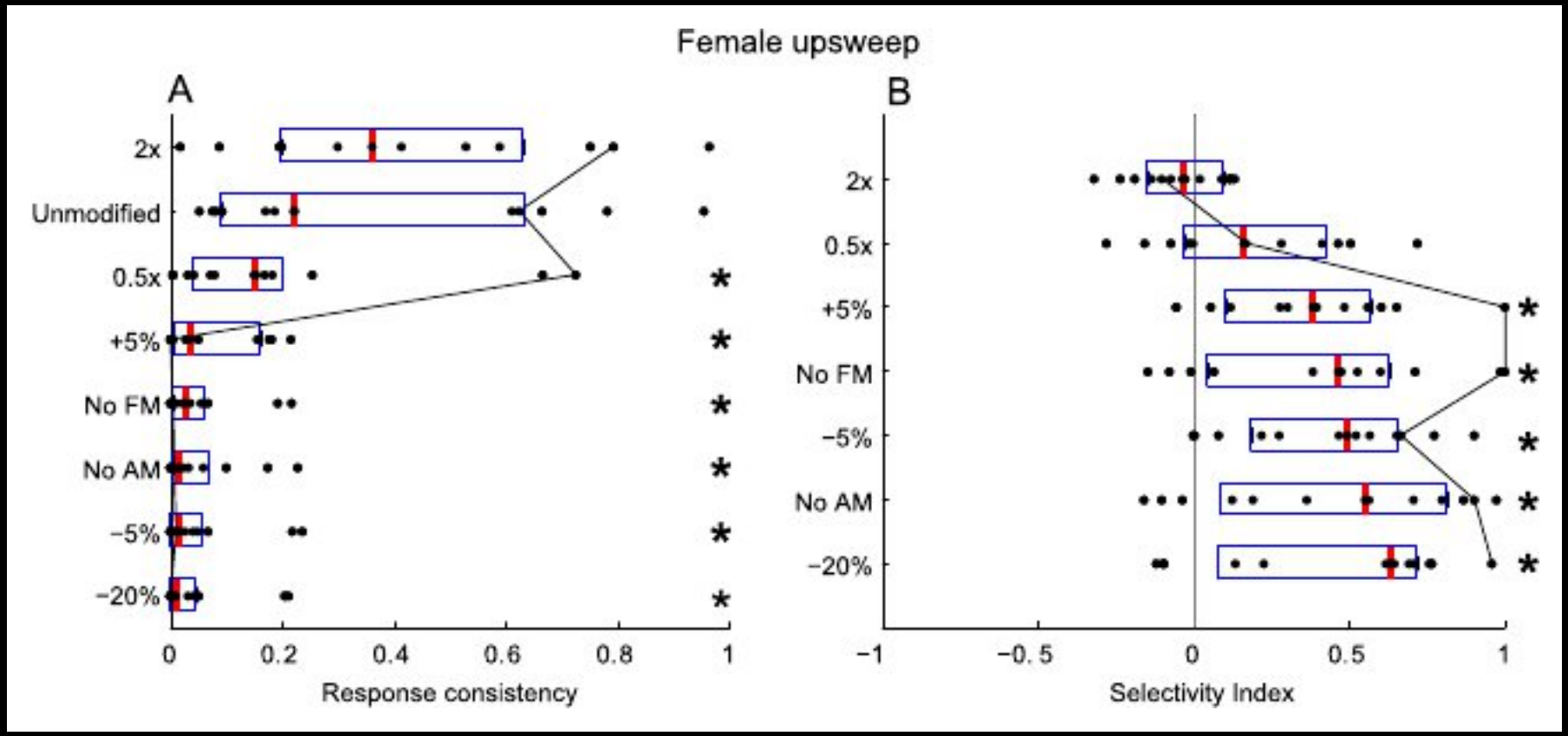
Perturbing Individual Neurons



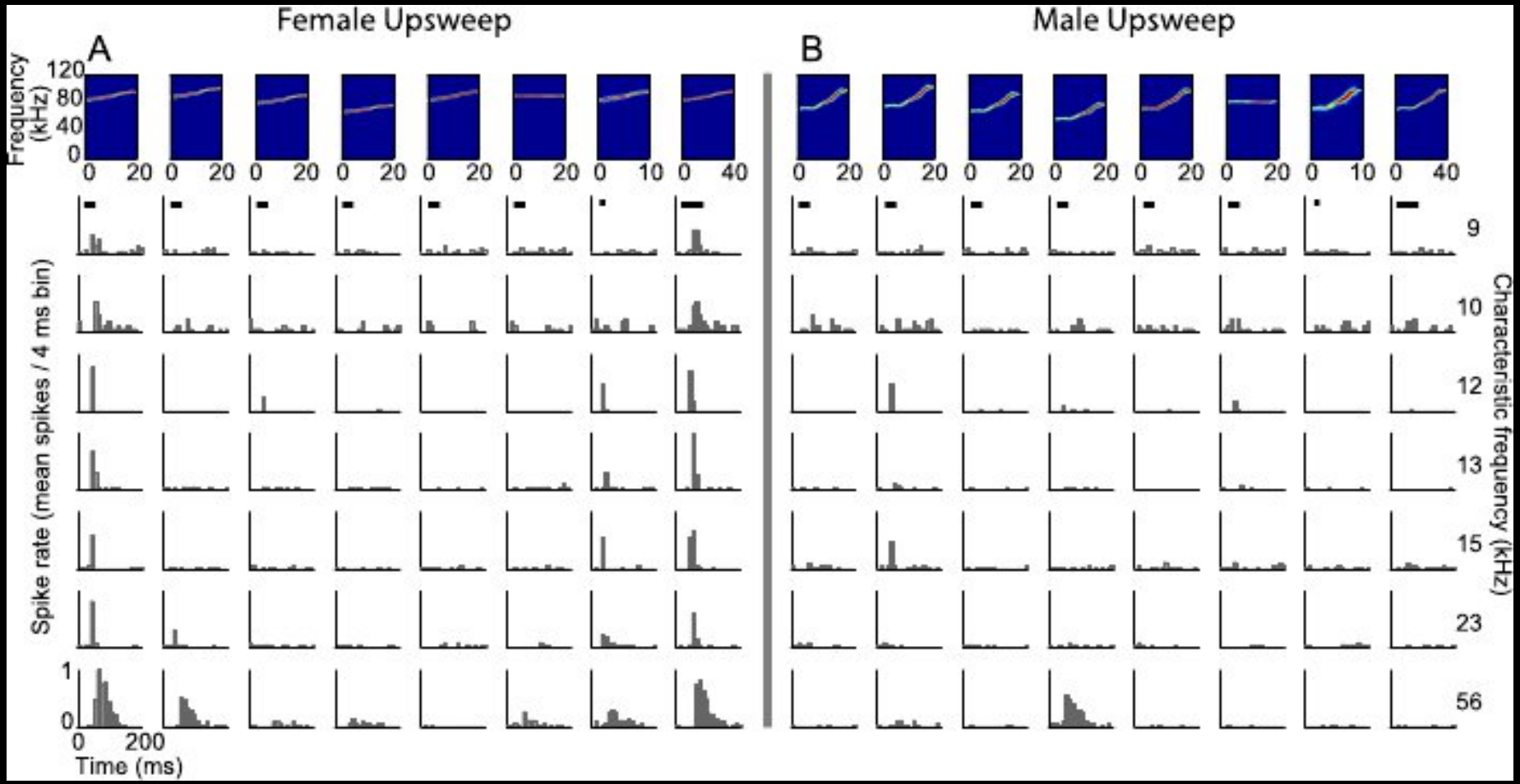
Neural Selectivity Among Vocalizations



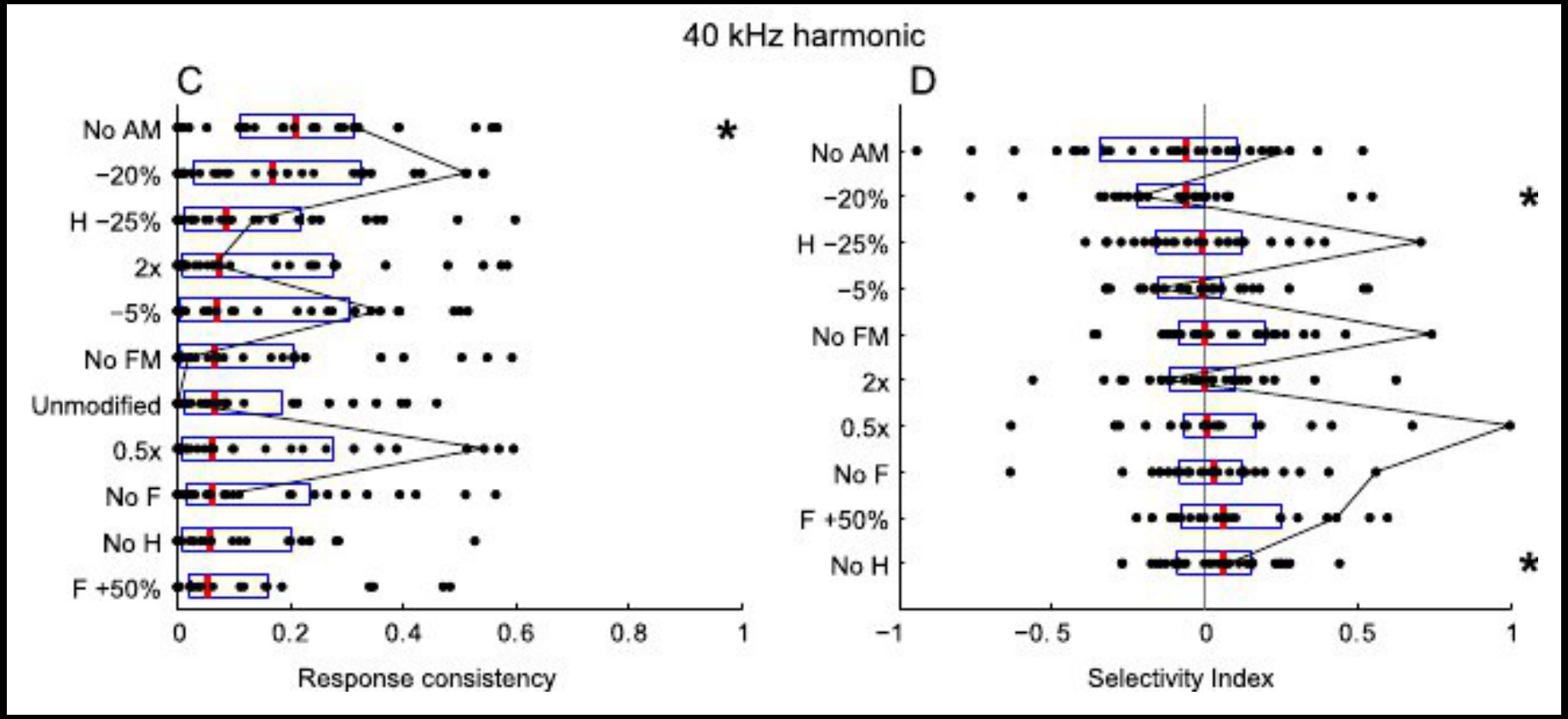
Population Selectivity Within Some Vocalizations



Population Selectivity (continued)



Neural Sensitivity and Heterogeneity Within Other Vocalizations



Both Strategies Lead to an Efficient Encoding Relative to the Periphery