Accounting for Complex Frequency Interactions in Predictions of Neural Responses to Social Vocalizations in the IC of the Mustached Bat

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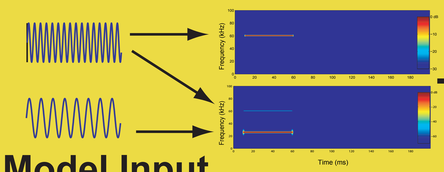
Introduction

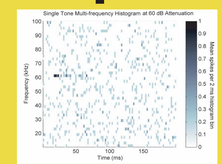
- The inferior colliculus (IC) of the midbrain is believed to be sensitive to complex features of auditory stimuli by integrating sensory input from multiple frequency bands and time delays
- In the mustached bat, these neurons are important for encoding echolocation signals
- It is hypothesized here that these neurons are also important for encoding the mustached bat's social vocalizations
- The purpose of this study was to quantify the contribution of complex frequency interactions on the responses of IC neurons to social vocalizations
- This was done by modeling the single and paired tone stimulus-response relationship of each neuron in the study (n=30) and analyzing the predicted response of the neuron to social vocalizations

Modeling Neural Responses



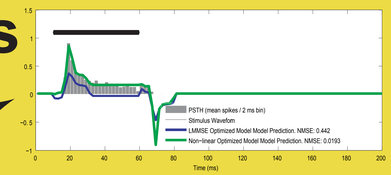
Model Input

- Single and paired pure tone stimuli
- Spectrograms were generated from the Input signals and normalized such that the integrated power was in units of dB SPL
- The spectrographic representation was driven by the hypothesis that auditory neurons receive multiple inputs from multiple frequency bands



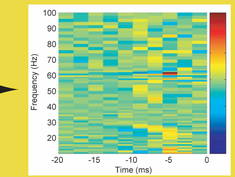
Model Targets

- The desired behavior of the model was to accurately reproduce the amplitude and temporal characteristics of the peristimulus time histograms (PSTH) for a particular cell in response to the training stimulus



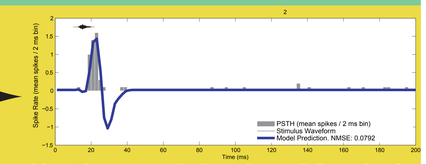
Training the Model

- Each frequency band (one per pure tone in the training data) was paired with a linear FIR filter
- The input to each filter was the time varying power of the stimulus, bandpassed for the filter's frequency
- The filter coefficients were first determined through a linear minimum mean squared error (LMMSE) optimization
- A gradient descent algorithm was then used to find the optimal parameters such that negative outputs are not penalized.



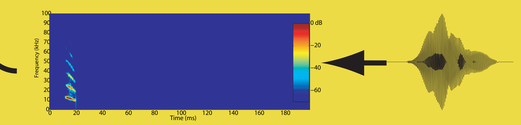
The Model

- Can be interpreted as the spectro-temporal receptive field (STRF) of the neuron



Predicting with the Model

- Each social vocalization was processed through the model to generate the predicted response
- These responses were then compared to the actual response of the cell

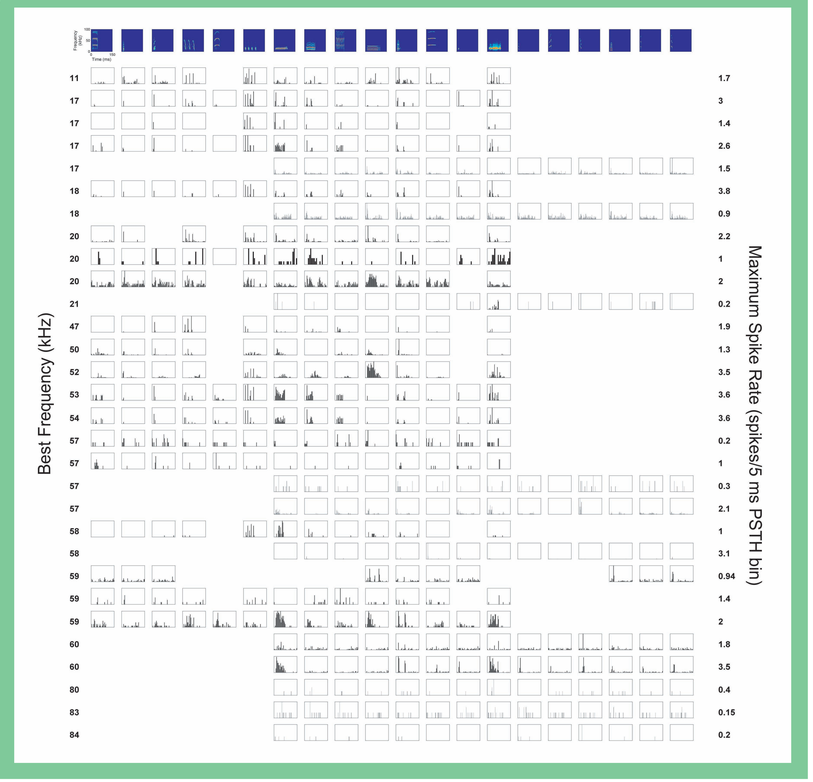


Neurophysiology Methods

- We used micropipette electrodes to record single unit responses in the IC of awake mustached ats to single tones, combinations of tones and social vocalizations
- The suite of social vocalizations consisted of vocalizations that mustached bats readily emit in captivity. These calls were provided by J. Kanwal. Our suite of vocalizations evolved over the course of the experiment, but each neuron was presented with a minimum of 10 different vocalizations
- Vocalizations were presented at varying intensities and presented 5-10 times at each intensity

Cell Responses to Social Vocalization Stimuli

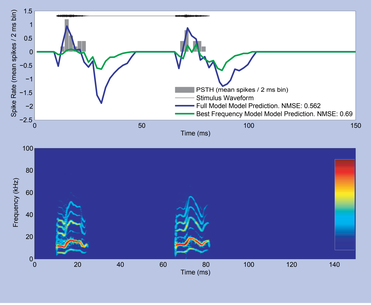
Individual neurons exhibit different types of selectivity to social vocalizations - even neurons with similar best frequencies (BF)

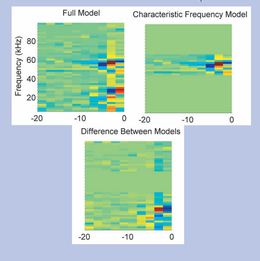


Results and Conclusions

Responses to social vocalizations are driven by inputs far off the best frequency (BF) of the neuron

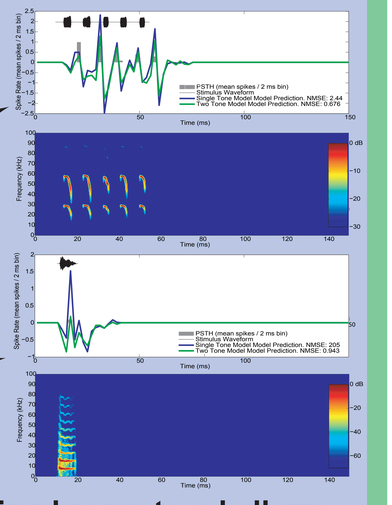
- Here, the paired tone model for this neuroni s compared to an identical model where all input farther than 20kHz away from BF is ignored
- The full model correctly predicts a response, where the BF model predicts no or little response

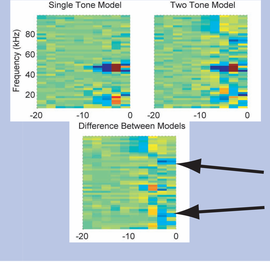




Selectivity to social vocalizations is driven by inhibitory inputs far off the best frequency (BF) of the neuron

- Both the single and paired tone models for this neuron correctly predict a response to this vocalization whose power is primarily in the neuron's BF excitatory input range
- The inhibitory inputs captured by the paired tone model result in a correct prediction of no response to this vocalization whose power also lies in the neuron's inhibitory input ranges, while the single tone model predicts a strong response





The paired tone stimulus protocol allows the model to capture additional inhibitory inputs present in the neuron and not captured by the single tone model