A Rat Model of Speech: Cortical Encoding of Vocalizations

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INTRODUCTION

Rats produce complex vocalizations in communicating with each other. Over 14 types of distinct calls can be distinguished in their repertoire (Clarke et al., 2009). Neurons in the primary auditory cortex respond selectively to con-specific vocalizations (Wang et al. 1995, Liu and Schreiner, 2007, Petkov et al, 2008, Huetz et al., 2009, Chandrasekaran et al., 2010). However, the precise mecha nisms of how complex vocalizations are encoded in the auditory pathway are not well understood. To learn how the auditory cortex encodes information about rat vocalizations, we presented a library of recorded and purified vocalizations to awake rodents, recorded neural activity in the auditory cortex and constructed a mathematical model that allowed us to predict A1 responses to novel vocaliza tions.

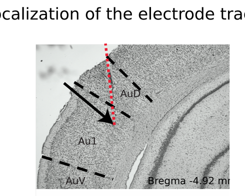
QUESTIONS

- Do cells in the auditory cortex respond selectively to vocalizations?
- Can we predict how a cell will respond to different vocalizations?
- How Do the responses compare if we distort the vocalizations?

CELLS IN AUDITORY CORTEX

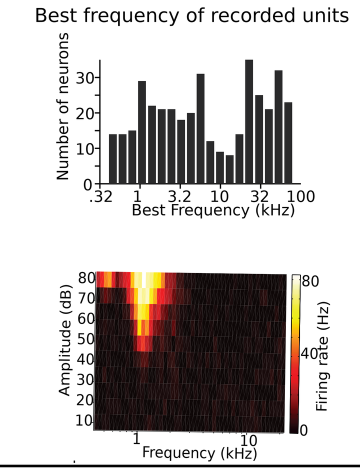
In order to record the responses of neurons in the auditory cortex, we implanted several rats with tetrode electrodes. Tetrodes are bundles of four wires, twisted tightly so that we can isolate the activity of many different cells by looking at how the signal compares across the four channels.

Localization of the electrode tract in A1



Networks of neurons pass information via what are called "action potentials", which are very fast pulses of electrical discharge. By recording these action potentials, or "spikes", we can identify what sorts of stimuli ellicit the most response from a particular neuron

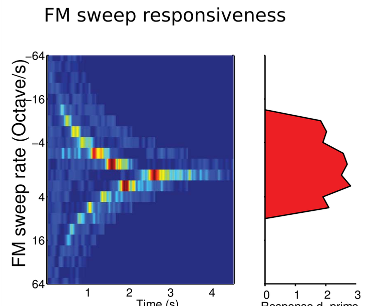
Best frequency of recorded units



A traditional example is a "frequency tuning curve" like the one ro the right. We play a long series of tones at different volumes and frequencies, and this gives us a picture of how much a cell tends to respond to different tones.

Another way we can examine the responses of cells is to expose them to tones that sweep upward or downward in frequency. This tells us whether cells prefer tones that sweep upward or downward, or tones that sweep faster or slower. We can use this sort of information to predict how cells will respond to other sounds.

FM sweep responsiveness



Acknowledgements

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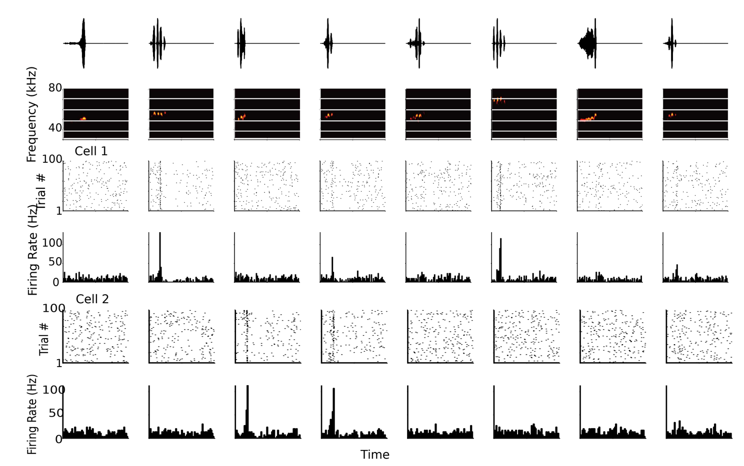
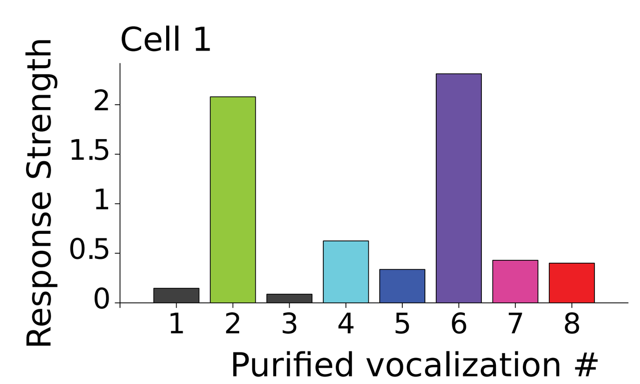
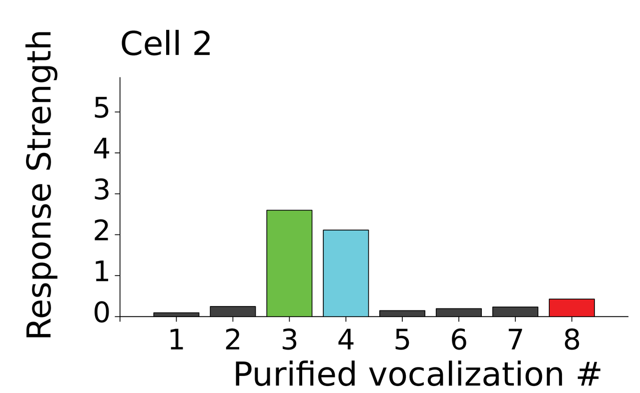
RESPONSES TO RAT VOCALIZATIONS

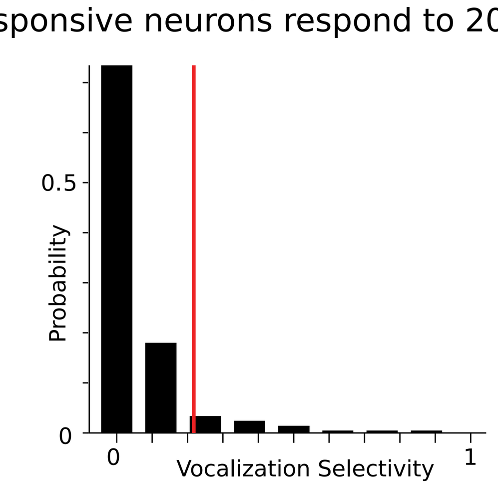


Different cells respond to different subsets of the vocalizations. We want to explain this effect in terms of the properties of the neurons.

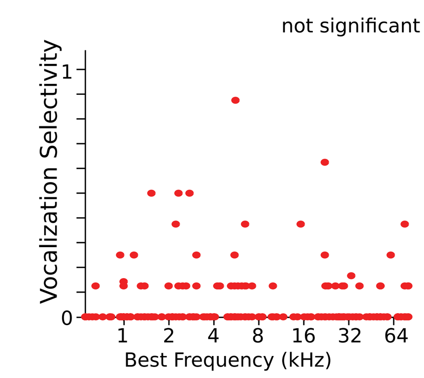




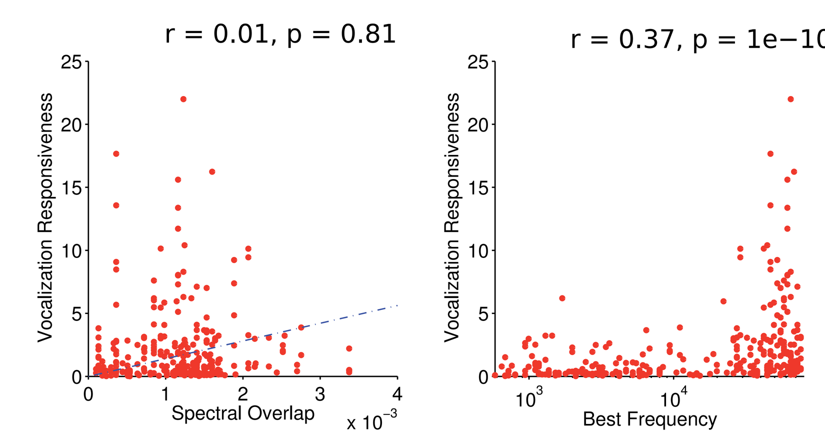
30% neurons respond to at least one USV
Responsive neurons respond to 20% of USVs



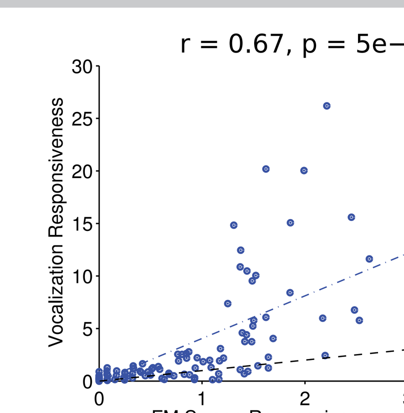
Spectral tuning is not correlated with vocalization selectivity



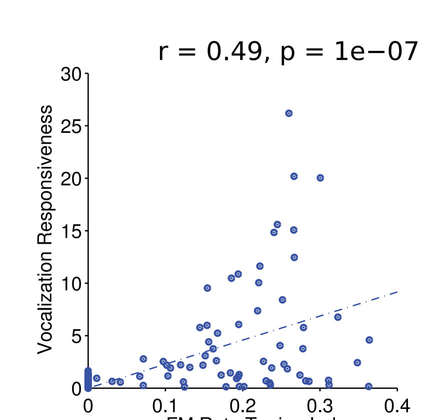
Spectral tuning is correlated with vocalization responsiveness



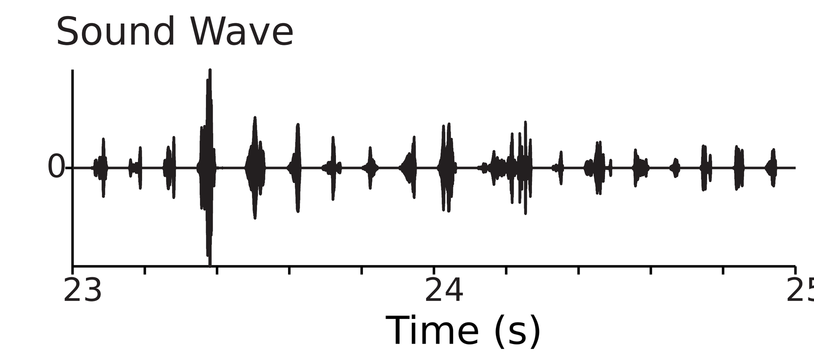
FM responsiveness is correlated with vocalization responsiveness



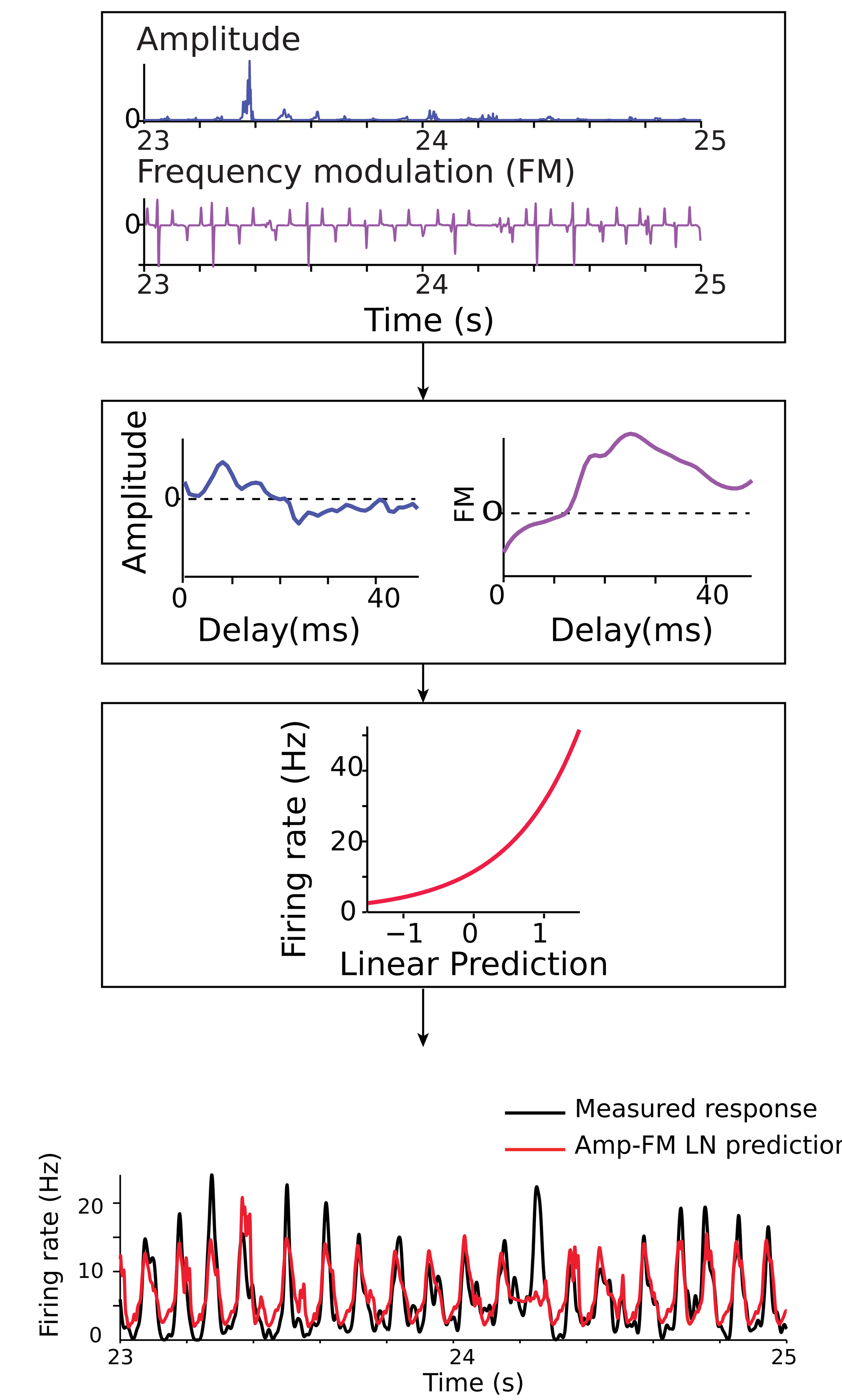
FM tuning index is correlated with vocalization responsiveness



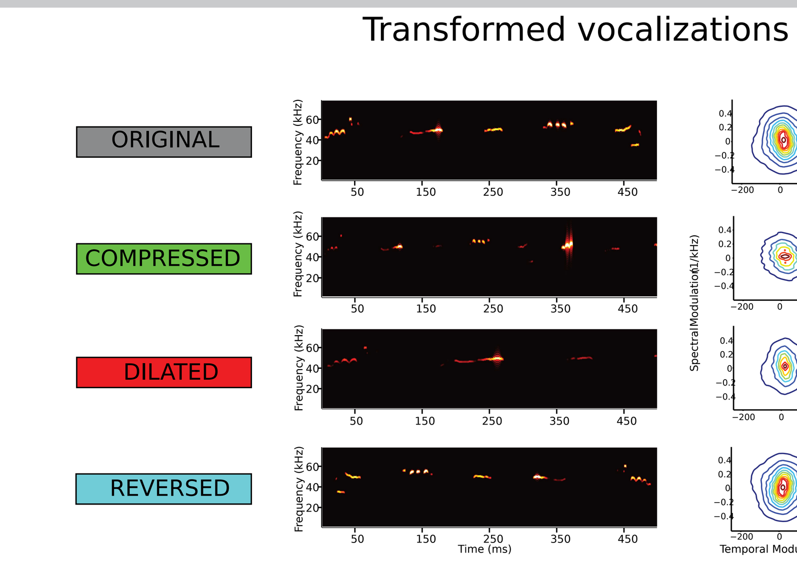
RELIABLE MODEL OF NEURAL RESPONSES TO VOCALIZATIONS



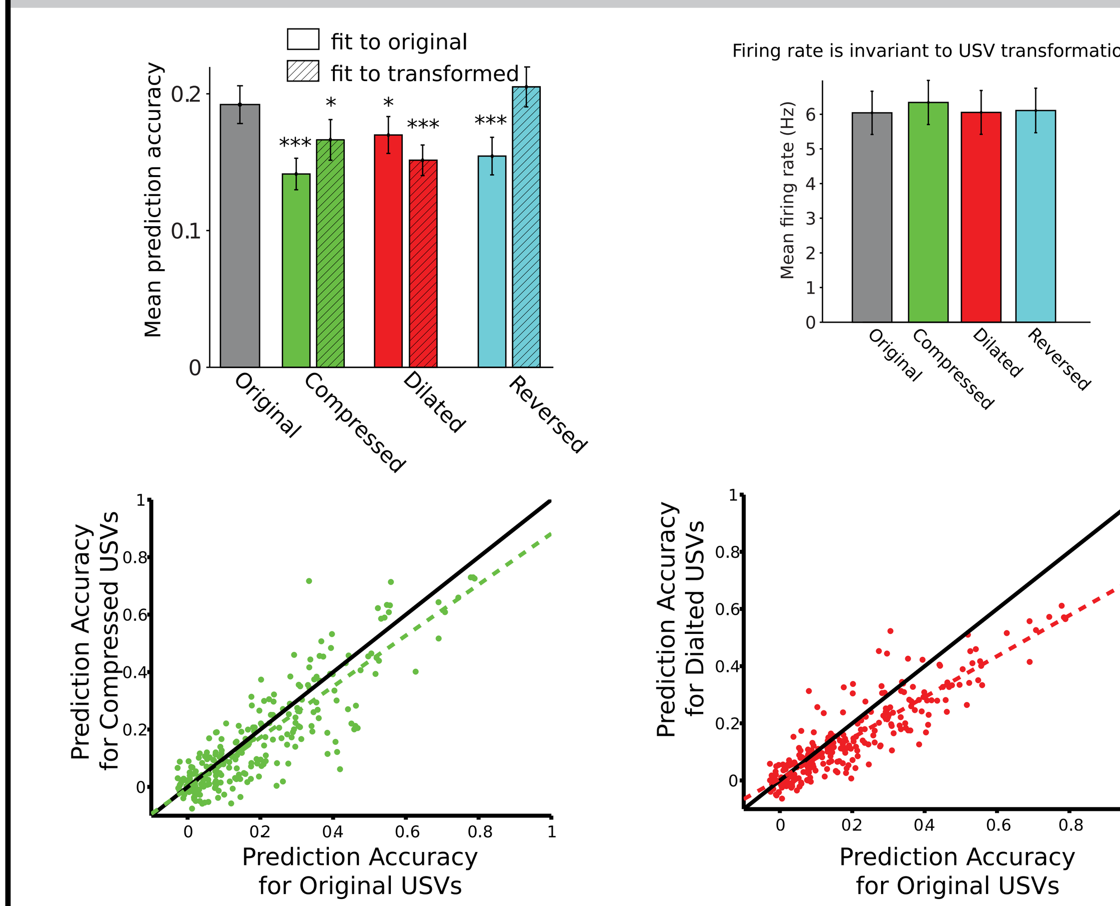
Amp-FM Linear-Non-Linear Model



ENCODING OF TRANSFORMED VOCALIZATIONS



Lower prediction accuracy for transformed vocalizations



CONCLUSIONS

A1 neurons respond selectively to a subset of USVs

Responses to USVs are correlated with responsiveness to fre quency modulation and spectral tuning

The responses are accurately predicted by a reduced LN model, based on integration of frequency modulation and amplitude

Responses are predicted less accurately to temporally transformed vocalizations suggesting a differential encoding mechanism specific to the temporal statistics of original USVs