Decoding the network rhythms of Zebra finch auditory LFP

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SUMMARY

Decoding the information embedded in multi-electrode local field potential (LFP) is needed in order to understand the dynamics of neural networks and enhance performance of brain-machine interfaces. Zebra finches are a powerful model for studying neural computations performed by the auditory system to extract meaning from communication sounds, since they produce a large repertoire of calls used in different behavioral contexts[1] (Fig 1). Here we describe how acoustic information can be decoded from the multi-electrode LFP of the Zebra finch auditory network and how that information is spatio-temporally distributed. First we trained decoders to predict acoustic features of syllables from multi-electrode LFP power spectra (Fig 2a). Analysis by frequency showed that the gamma band contains information about spectral envelope and amplitude of vocalizations, while higher frequencies (> 80Hz) contain temporal envelope properties (Fig 2b). Decoders utilized spatial patterns of LFP power spectra to make predictions (Fig 2c). We then performed an analysis of the spatio-temporal pattern of LFP activity in the low gamma band, and found that it was highly correlated with population spike rate, during both stimulus evoked and spontaneous activity (Fig 3a). Some neurons fired during particular phases of spontaneous gamma activity, and lost that phase preference during stimulus evoked activity (Fig 3b). Fitting a coupled oscillator model to multi-electrode low gamma, we found that coupling is strongest between thalamic recipient region L2, and superficial layers CM and L1 (Fig 3c). Coupling strength is distance-dependent, decaying quickly within 500um, but enhanced by regional effects (Fig 3d). Taken together, these results portray the L2/CM/L1 complex as a functional network connected with secondary region NCM, and supports a model for avian auditory cortex that considers these regions as the primary auditory area[2]. Finally, we found that the entire network carries rich stimulus information about acoustic features, accessible via spatial patterns in the gamma band LFP.

ADDITIONAL DETAILS

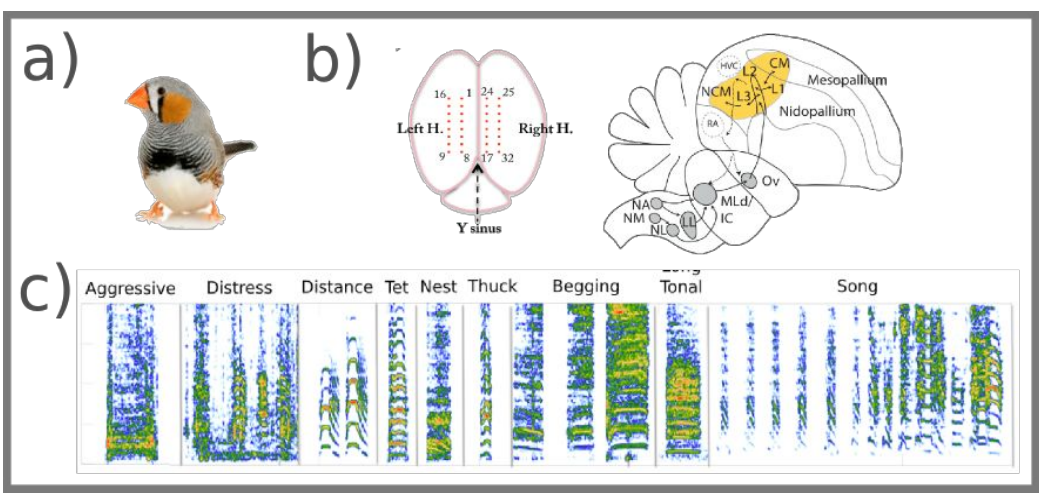

Fig. 1: Experiment
(a) Dual hemisphere multi electrode recordings were performed in 6 anaesthetized zebra finches.
(b) Two 8x2 electrode arrays were placed perpendicular to primary and secondary auditory areas, shown in yellow.
(c) Spectrograms of different calls from the Zebra finche repertoire used in these neural recordings.

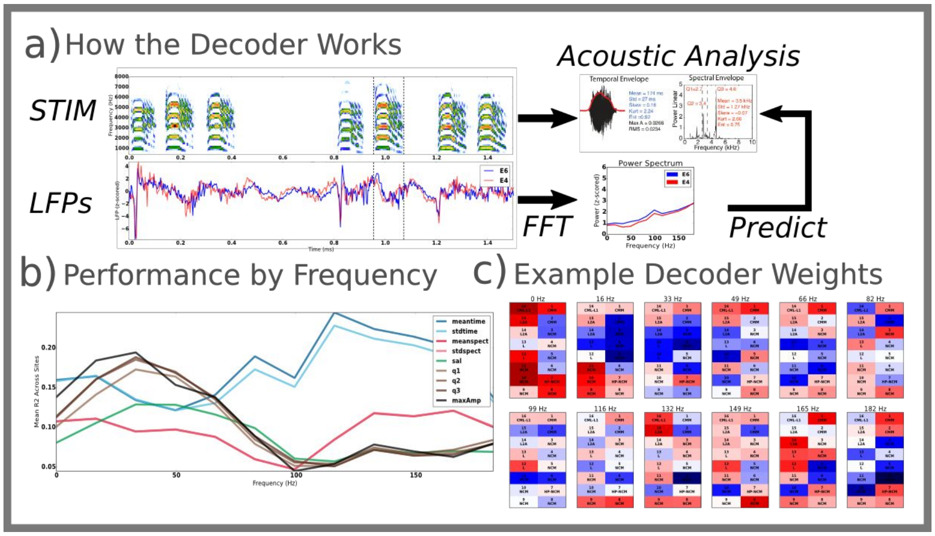

Fig. 2: The Decoder
(a) A series of distance calls are played (STIM) while the LFP is recorded simultaneously from the electrode array (LFPs). Responses from two electrodes (red and blue traces) are shown. A syllable is isolated (dashed lines) and the acoustic features of that syllable are extracted (Acoustic Analysis). The power spectrum of each trial-averaged LFP conditioned on the syllable is computed (FFT) and z-scored. The decoder utilized regularized linear regression with 10-fold cross validation to optimally predict each acoustic feature (Predict). (b) A performance plot for multi-electrode decoders trained on individual frequency bands, for each acoustic feature. Black and brown traces, representing syllable amplitude and quantiles of the spectral envelope, respectively, dominate decoding performance for the gamma frequency band (15-80 Hz). (c) The weights for a decoder trained on all electrodes and frequency bands shows that predictions are obtained by a weighted combination of power across frequency and space.

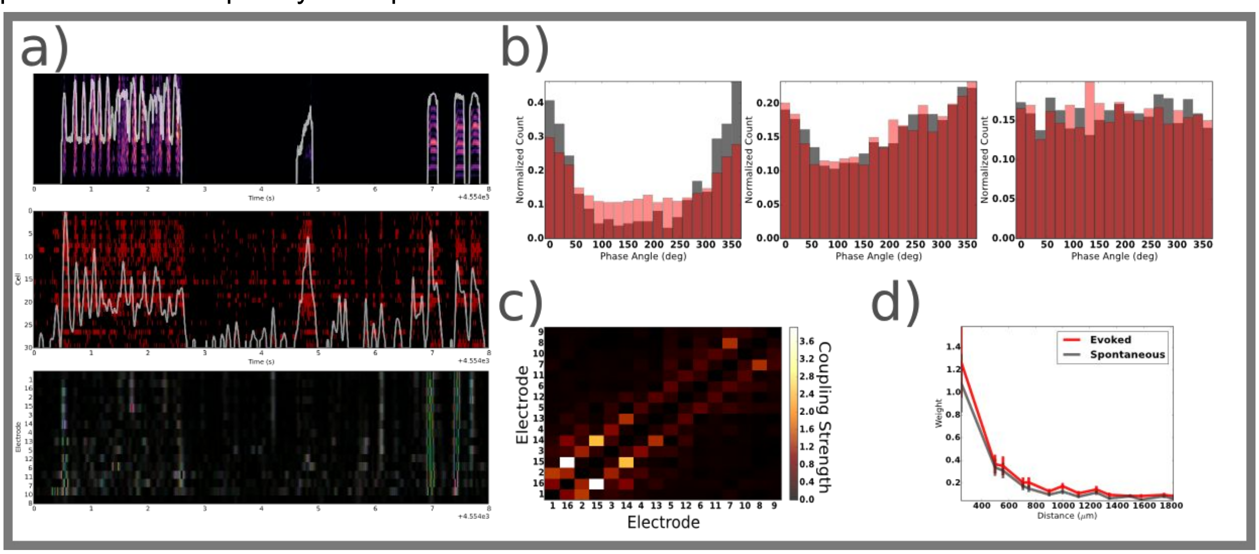

Fig 3: Low Gamma Spatio-Temporal Coupling: (a) A plot of the vocalizations played to the bird during recording (top), neuron spike rasters recorded on one array (middle), corresponding multielectrode gamma phase and amplitude (color and brightness, bottom row). (b) Phase preferences of three different neurons. Histograms of phase during spontaneous spikes (gray) are overlaid with phase histograms during evoked spikes (red). Neurons are classified from high preference (left) to no preference (right); the first neuron reduces phase preference during evoked activity. (c) Matrix of coupling strengths, element i,j is the coupling between electrodes i and j. Electrodes on the lower left quadrant are in Field L, CM, and L1, neurons on the upper right are in NCM. (d) Coupling strength as a function of distance, for evoked (red) and spontaneous (gray) activity.

References: 1. Elie, J. E. and F. E. Theunissen (2015). "Meaning in the avian auditory cortex: neural representation of communication calls." *EJN* 41(5): 546-567; **2.** Wang, Y., A. Brzozowska-Prechtl and H. J. Karten (2010). "Laminar and columnar auditory cortex in avian brain." *PNAS* 107(28): 12676-12681.