A Gaussian process model of human ECoG data

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Introduction & intuition

There is inherent compromise between high temporal and high spatial resolution in current human brain recordings.

ECoG has both high spatial and temporal resolution, but has minimal brain coverage for individual patients. However, there is good coverage across patients.

Our technique leverages correlational activity across patients, in conjunction with known activity, to infer activity at other unrecorded locations.

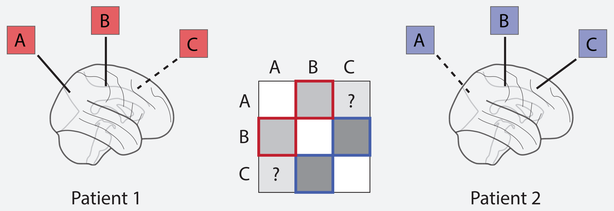

Figure 1. Intuition of the approach. If we know how activity in locations A and B are correlated in patient 1 and we know how activity in locations B and C in patient 2 are correlated, and if patient 1 and 2 share some correlation, then we can predict activty at missing locations.

General approach

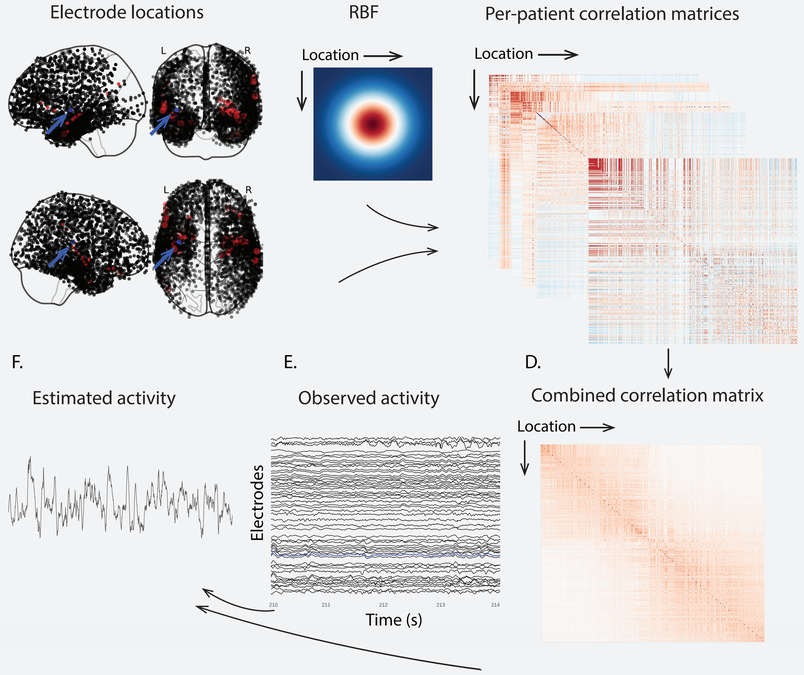

Figure 2. A. All electrode locations (one patient's electrodes in red and the to-be-reconstructed electrode in blue). B. Calculate weights using radial basis function (RBF) . C. Use RBF-weighted averages to estimate correlation between each patient's electrode locations and all locations. D. Average patient-specific correlation matrices. E. & F. Use the observed activity (E) for from patient's electrodes and the estimated correlation (D) to compute the posterior mean (F).

Reconstruction accuracy

To test the accuracy of the estimated activity, we held out each electrode from the full dataset — treating it as an unobserved location. We estimated the combined correlation matrix for every other patient's data. Using this new combined correlation matrix, we estimate the activity for the held out electrode, and compare it to the observed activity.

We repeated this process for all electrodes, collecting correlation values for each electrode location. Then, we repeated this procedure across six frequency bands and broadband power.

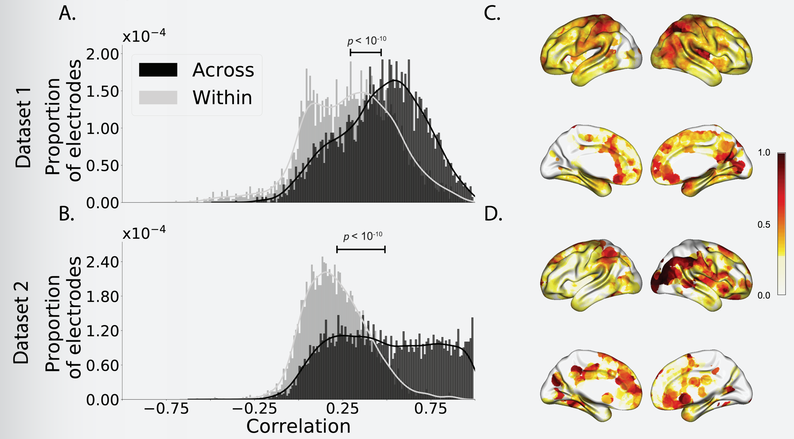

Figure 3. A, B. Distributions of correlations between observed versus reconstructed activity by electrode. C,D. Reconstruction accuracy across location.

Frequency breakdown

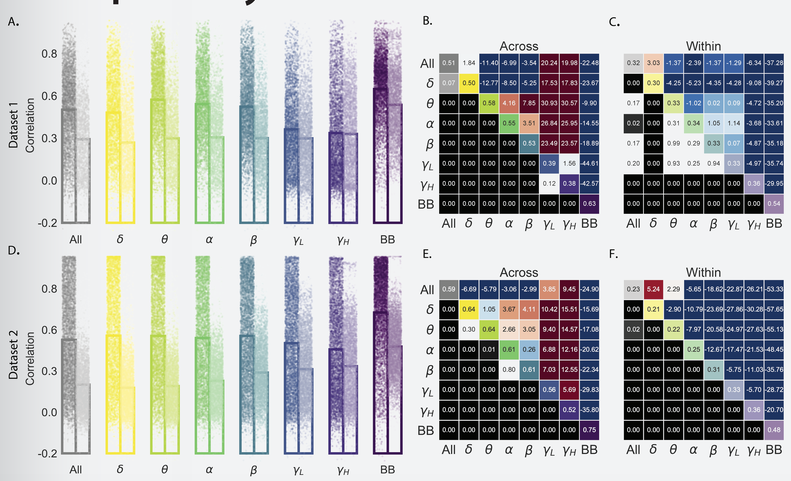

Figure 4: Reconstruction accuracy across all electrodes in two ECoG datasets for each frequency band. A-D. Distributions of correlations between observed versus reconstructed activity by electrode for each frequency band in Dataset 1. Within each color group, the left bar displays the distribution of across-patient reconstruction accuracies, while the right bar displays within-patient reconstruction accuracies.

B-C-E-F. Upper triangles: warmer colors (positive t-values) indicate that the reconstruction accuracy for the given row was greater than in the given column; cooler colors (negative t-values) indicate the accuracy was lower. Lower triangles denote the corresponding p-values for the t-tests, and the diagonal displays the average reconstruction accuracy within each frequency band.

Most informative locations across networks and frequency bands

To quantify a location's "information score," we first labeled each patient's electrode with the average reconstruction accuracy for that patient. Next, for each 4 mm^3 voxel, we computed the average value across all electrodes within 20 MNI units of that voxel's center. This yielded an information score for each voxel.

Overlaying Yeo et al.'s (2011) seven-network parcellation map onto brain locations that were most informative about each frequency band, we computed the proportion of voxels that belonged to each of the seven networks (Fig. 6D).

We used Neurosynth (Rubin et al. 2017) to identify (using meta analyses of the neuroimaging literature) the top five most common terms associated with each frequency-specific map (Fig. 6C).

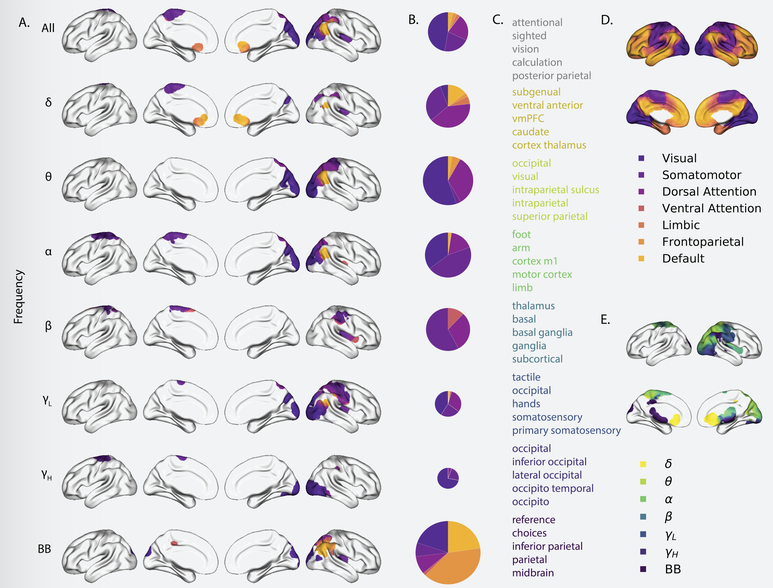

Figure 5. Most informative recording locations by frequency band. A. Intersections between information score maps by frequency band. B. Network memberships of the most informative brain regions. C. Neurosynth terms. D. Network parcellation map and legend by Yeo et al. (2011). E. Combined map.

Future directions

There are a number of future directions, both methodologically and practically, in which our method might be extended.

Incorporation of fMRI and DTI data as well as more sophisticated Gaussian process models could increase the power and accuracy of the method.

There is also potential for addressing potential future therapeutic applications, both in epilepsy and other comorbid diseases. Our method and software package, SuperEEG, has already been applied to detecting depression biomarkers (Scangos et al.).

For questions, comments, or reprints visit our website: http://www.context-lab.com
Read more: https://www.biorxiv.org/content/10.1101/121020v3 SuperEEG package: https://github.com/contextlab/supereeg

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