Decoding task and location information from multi-unit and local field potential activity

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Introduction & overview

We examined recordings from neurosurgical patients as they played a virtual navigation game, *Yellow Cab*.

We studied how navigationally relevant information about participants' current task and location is reflected in various components of the neural recordings.

We found that the best predictors of participants' task and location were:
- broadband (non-oscillatory) components of the local field potential (LFP)
- pairwise products of the firing rates of neurons from different brain regions

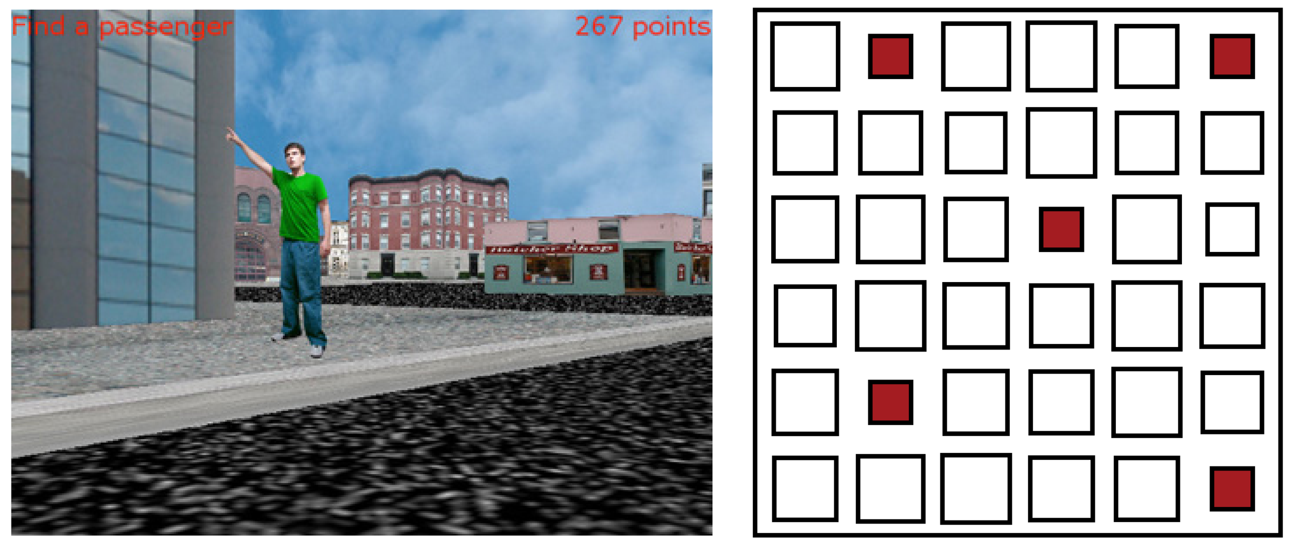

Figure 1. Participants assumed the role of virtual taxicab drivers and attempted to deliver passengers to their requested destinations in a series of virtual reality towns.

Methods

We constructed feature vectors comprised of:
- spectral features of LFPs
- single-neuron firing rates
- products of pairs of single-neuron firing rates

We trained Support Vector Machines to predict when the participant was:
- searching for vs. delivering a passenger
- in each of the four quadrants of the environment

We used the classifier weights to determine the relative predictive powers of different neural features.

We asked which neural features and brain regions were best at predicting participants' task and location in 500 ms epochs throughout the experiment.

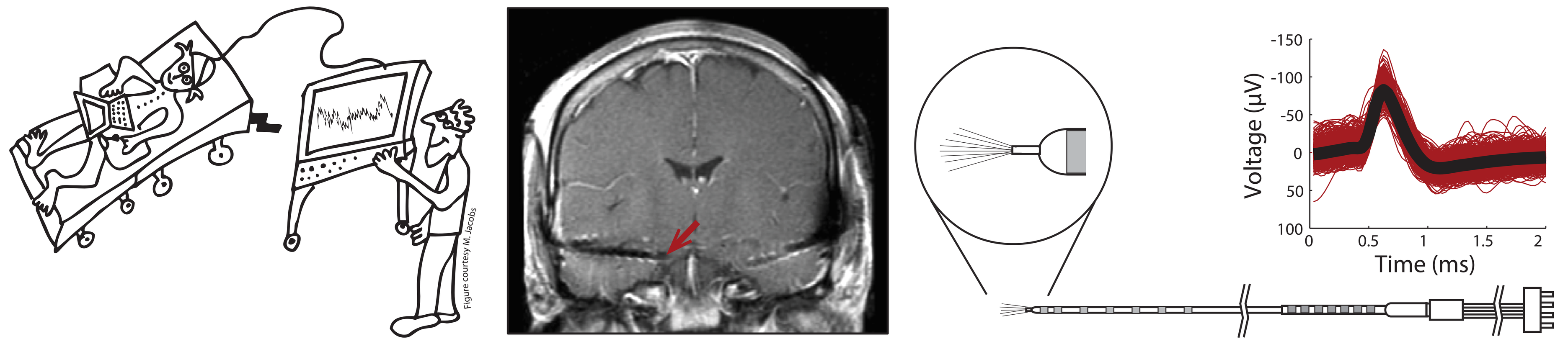

Figure 2. We recorded intracranial brain signals from 13 neurosurgical patients. Participants had 6-12 depth electrodes implanted bilaterally in widespread brain regions. Each depth electrode was augmented with a set of 9 microwires extending from its tip. We isolated 0-3 neurons per microwire, yielding 1,621 neurons in all.

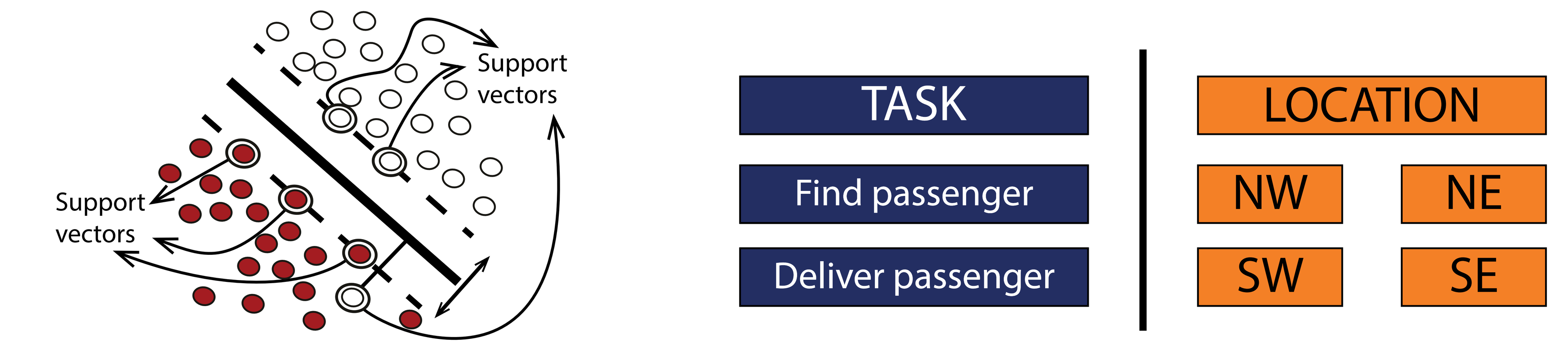

Figure 3. We used Support Vector Machines to classify participants' task and location. The left panel is modified from Ustun (2003).

Results

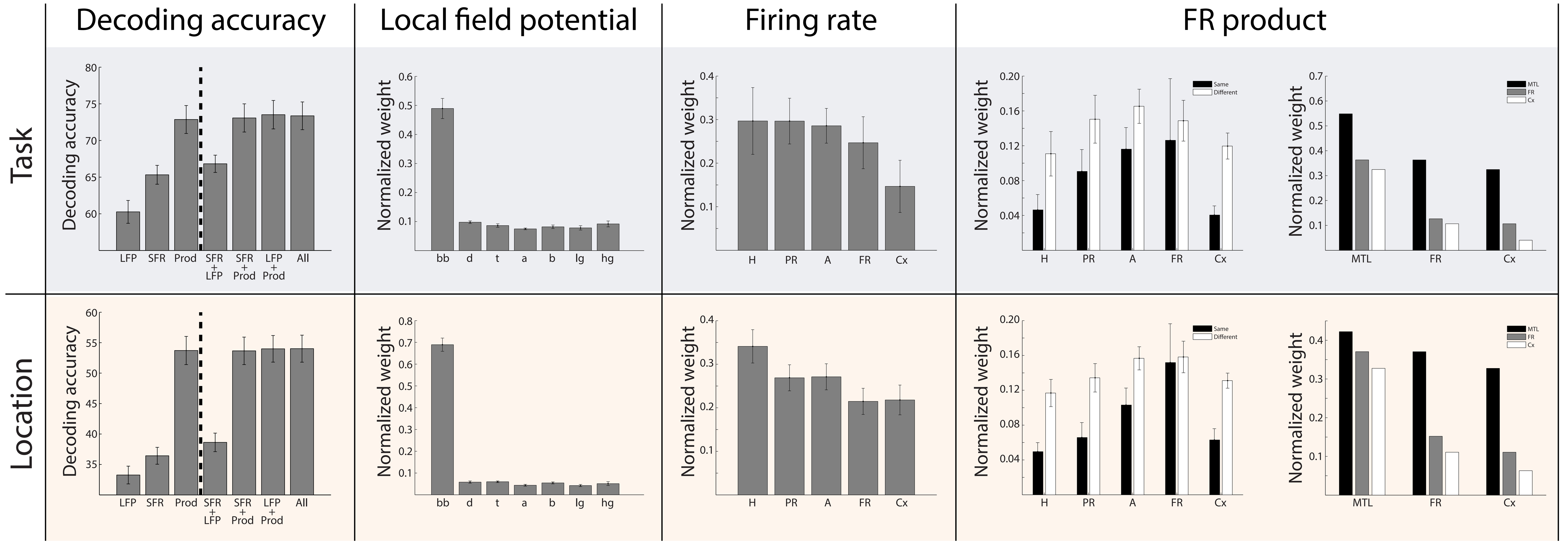

Figure 4. The leftmost panels display the mean 10-fold cross validation accuracy obtained using feature vectors comprised of spectral features of the local field potential (LFP), single-neuron firing rates (SFR), pairwise products of firing rates (Prod), and combinations thereof. The right panels display mean normalized weights assigned to different neural features. LFP features: broadband power (bb), 2-4 Hz (d)elta power, 4-8 Hz (t)heta power, 8-12 Hz (a)lpha power, 12-30 Hz (b)eta power, 30-50 Hz low gamma power (lg), and 80-120 Hz high gamma power (hg). Firing rate features were broken down by brain region and interactions between brain regions: Medial temporal lobe (MTL; includes (H)ippocampus, parahippocampal region (PR), and (A)mygdala), (FR)ontal cortex, and posterior cortex (Cx; includes parietal and occipital cortex).

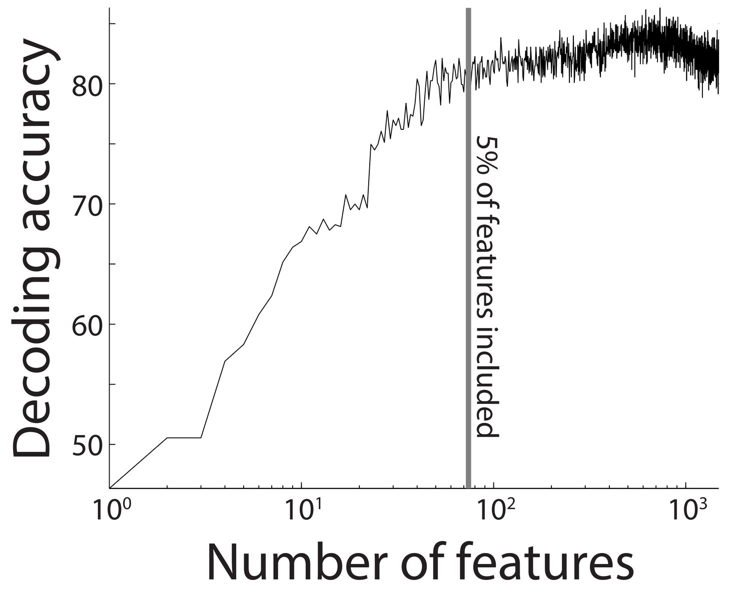

Figure 5. We used a recursive feature elimination analysis to estimate redundancies in the feature vectors. We trained SVMs to decode task information using all available features. We iteratively eliminated the feature with the lowest weight, re-computed classifier weights, and re-evaluated decoding accuracy. For the participant shown, peak decoding accuracy (using all 1,484 features) was approximately 85%. However, using just 5% (74) of those features maintained 81% accuracy.

Summary & conclusions

Each type of neural component we measured yielded above-chance decoding accuracy of participants' task and location.

Products of pairs of single-neuron firing rates that included MTL neurons were particularly informative.

Our findings provide insights into how large populations of neurons support navigation.

An important goal of future work will be to gain insights into the computational implications of our findings, and to tie these insights in with existing place cell, grid cell, and oscillation-based models of navigation.

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