Brain activity recorded during free viewing of naturalistic short films simultaneously reveals the brain representations of multiple feature spaces

Anwar O. Nunez-Elizalde (anwarnunez@berkeley.edu)
Helen Wills Neuroscience Institute, UC Berkeley
Berkeley, CA 94720 USA

Fatma Deniz (fatma@berkeley.edu)
Helen Wills Neuroscience Institute, UC Berkeley
Berkeley Institute for Data Science, UC Berkeley
Berkeley, CA 94720 USA

James S. Gao (jamesgao@berkeley.edu)
Helen Wills Neuroscience Institute, UC Berkeley
Berkeley, CA 94720 USA

Jack L. Gallant (gallant@berkeley.edu)
Helen Wills Neuroscience Institute, UC Berkeley
Department of Psychology, UC Berkeley
Berkeley, CA 94720 USA

Abstract

The human cerebral cortex comprises many functionally distinct areas that represent different information about the world. It has been challenging to map these areas efficiently. Here we present a new approach that addresses this problem. Subjects watch 30 interesting short films while their brain activity is measured with fMRI. The short films contain speech, video, music, environmental sounds, emotions, human interaction and narrative structure. Each film was labeled using more than a dozen different high-dimensional feature spaces reflecting the visual, auditory and conceptual content of the films. In effect each feature space constitutes a different hypothesis about how visual, auditory and conceptual information might be represented in the brain. Brain activity elicited by the films is then modeled using a novel voxelwise encoding model based on simultaneous Tikhonov regularization of the labeled feature spaces using a multivariate normal prior. The resulting encoding model reveals which specific feature spaces are represented in each voxel, and how each voxel is tuned with respect to those features.

To validate the approach we examined voxelwise model predictions using 27 minutes of novel short films not used for model estimation. We find that the voxelwise encoding model significantly predicts activity of voxels distributed broadly across the cerebral cortex. Model prediction accuracy is highest for voxels located in sensory regions such as early visual cortex, primary auditory cortex and regions related to language processing (Brocas, superior premotor ventral, and superior temporal gyrus). Significant predictions are also found for voxels located in association regions in prefrontal cortex (superior and inferior frontal gyri) and lateral parietal cortex, though these predictions are poorer than those for sensory and language regions. Furthermore, we find that the pattern of feature selectivity across cortex is highly consistent across all five individual subjects. Finally, we show that motion energy and spectrogram feature spaces recover known visual retinotopic and auditory tonotopic maps. The recovered feature spaces can capture novel functional subdivisions, even within well-studied regions such as middle temporal cortex.

Keywords: voxelwise encoding models; naturalistic stimuli

Acknowledgments

Funding provided by NIH NEI EY022454 and NIH NEI EY019684.