Are Faces, Places and Objects Encoded Everywhere in the Brain?

Zihan Neuki Li, Y. Ivette Colón, Kushin Mukherjee, Sachi Sanghavi, Timothy T. Rogers

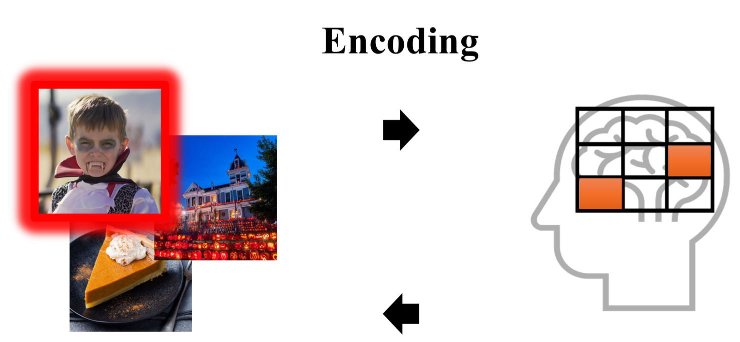
Rogers Lab

WISCONSIN INSTITUTE FOR DISCOVERY

Department of Psychology
UNIVERSITY OF WISCONSIN–MADISON

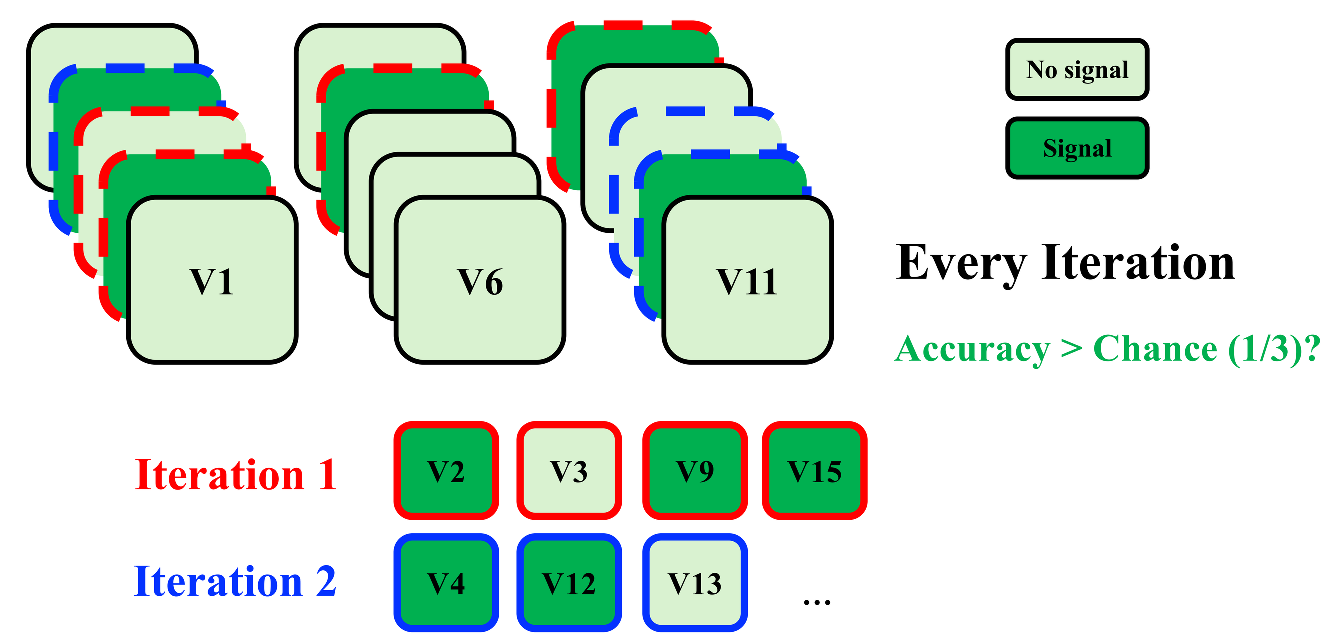
Reliable Semantic Neural Decoding with Iterated LASSO and Knockoff+

Machine Learning in Neural Decoding

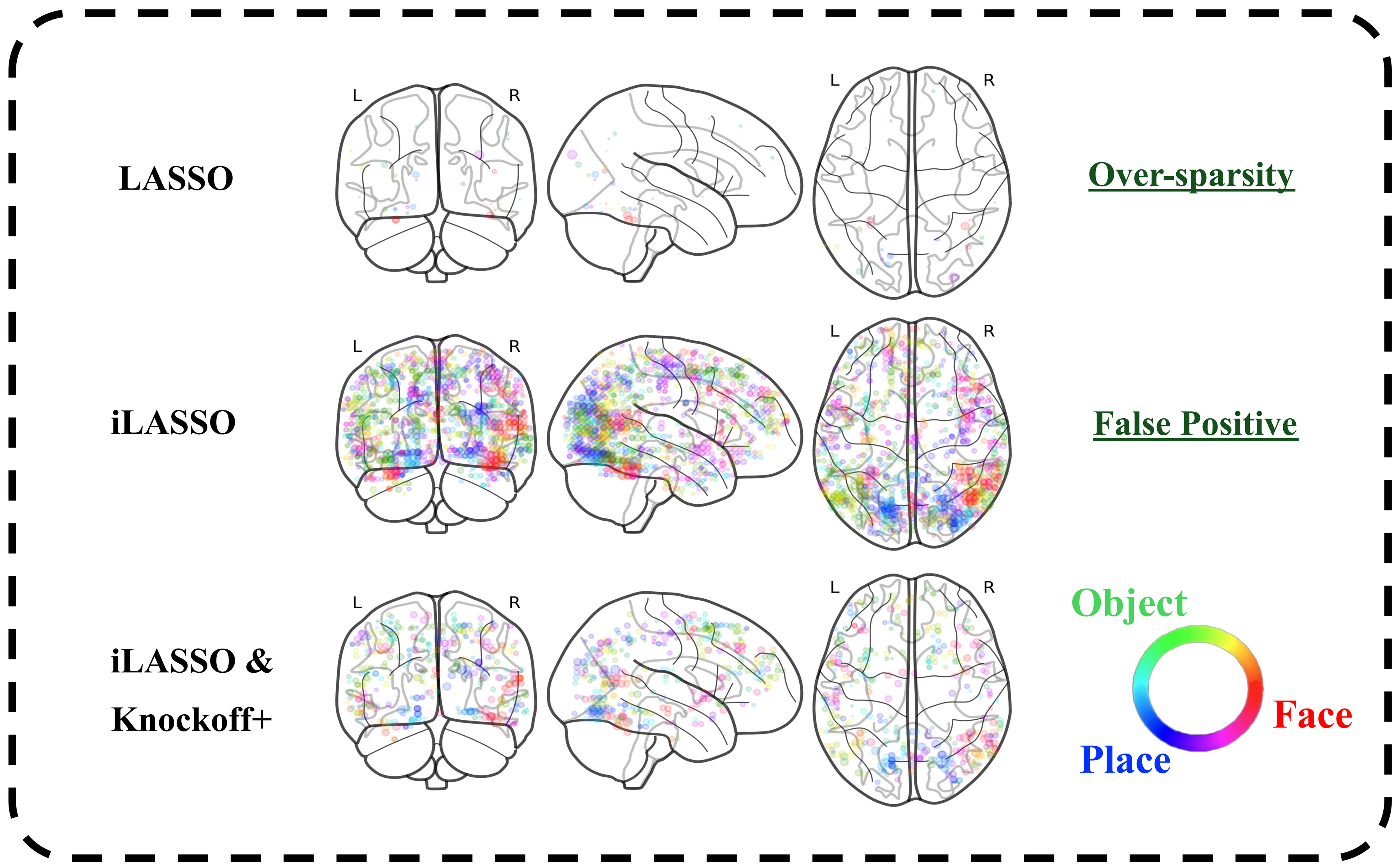


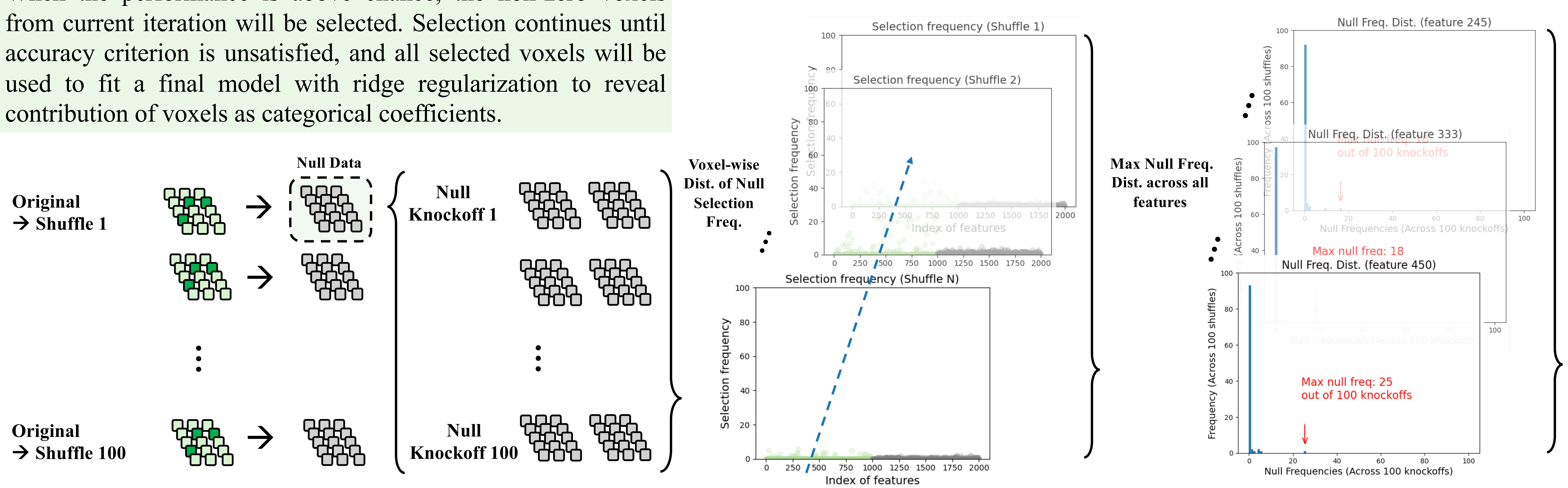
① Semantic information of visual stimuli is encoded in the brain. When we see them, the brain will be activated to recognize the stimuli and process the information. The activation patterns are semantic neural representations, and could be collected as voxel data by functional magnetic resonance imaging (fMRI). We decode neural representations by fitting predictive classification models and find out predictive voxels and their activation patterns. Traditional localized methods for neural decoding overlooked the distant relationships and distributed clues. Recent studies have applied machine learning with regularization on whole-brain data to decode, and revealed highly distributed neural representations. Current study validated the widely distributed neural representations, even after strict positive control.

Iterated LASSO: Find Out All Codes

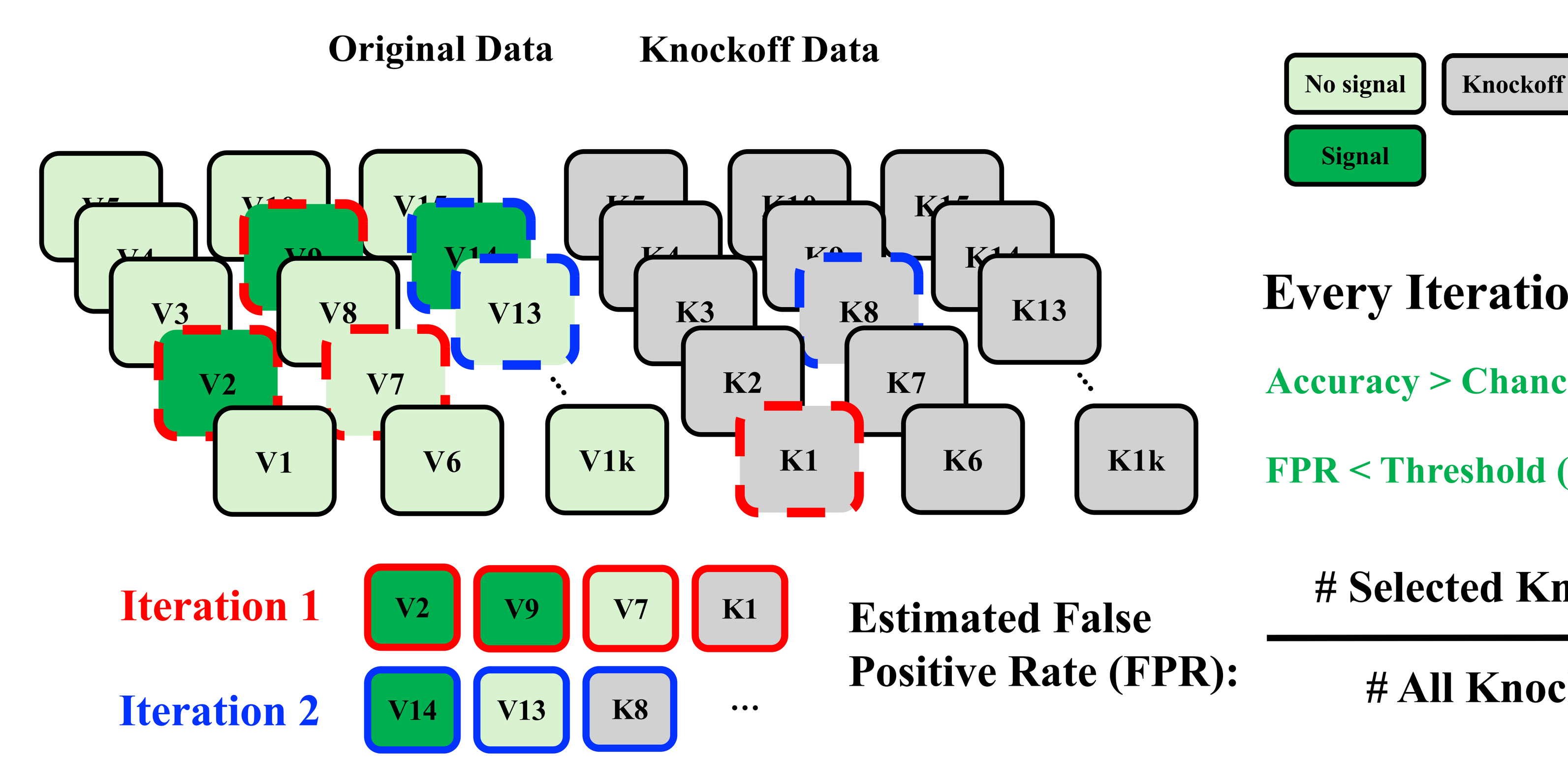


② We developed Iterated LASSO (iLASSO), to inclusively select out all predictive voxels in fMRI data. In each iteration a LASSO GLM model is fitted with the examination of prediction accuracy. When the performance is above chance, the non-zero voxels from current iteration will be selected. Selection continues until accuracy criterion is unsatisfied, and all selected voxels will be used to fit a final model with ridge regularization to reveal contribution of voxels as categorical coefficients.





Knockoff+: Filter Out False Positive Signals



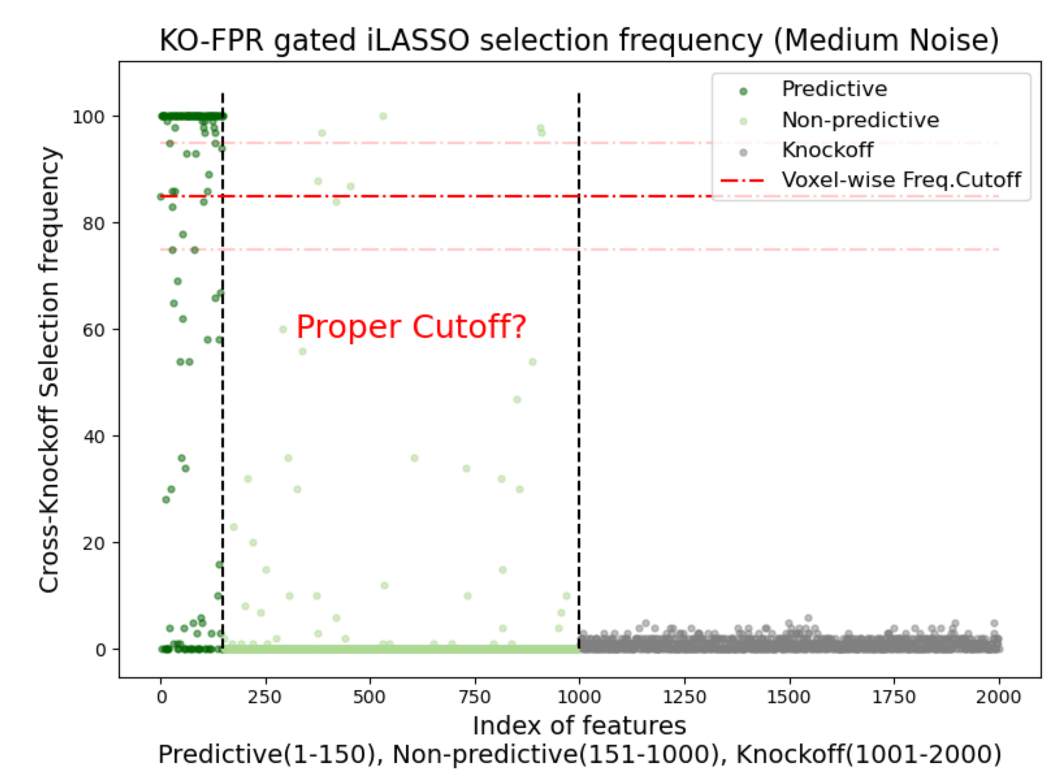
Every Iteration

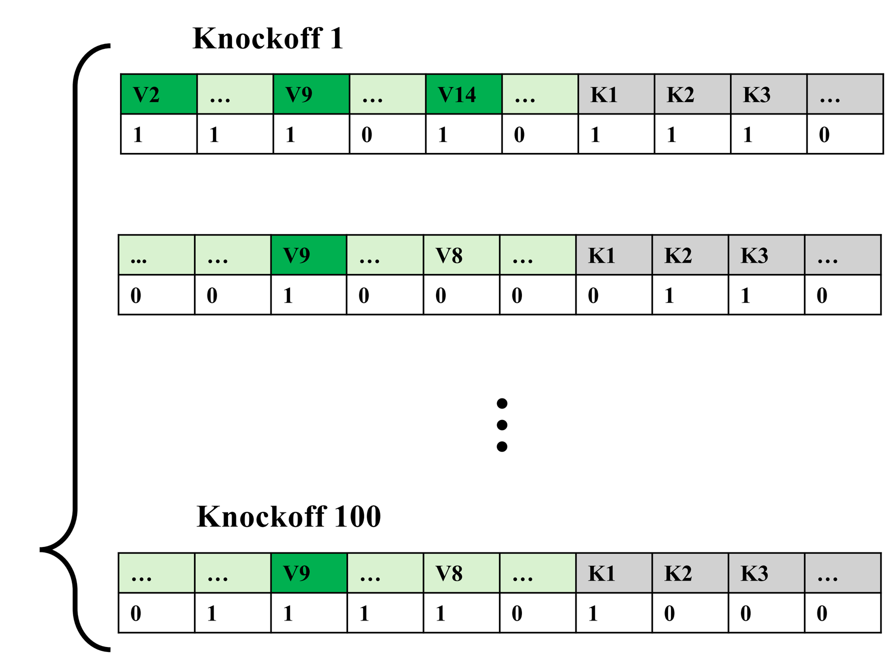
Accuracy > Chance (1/3)?

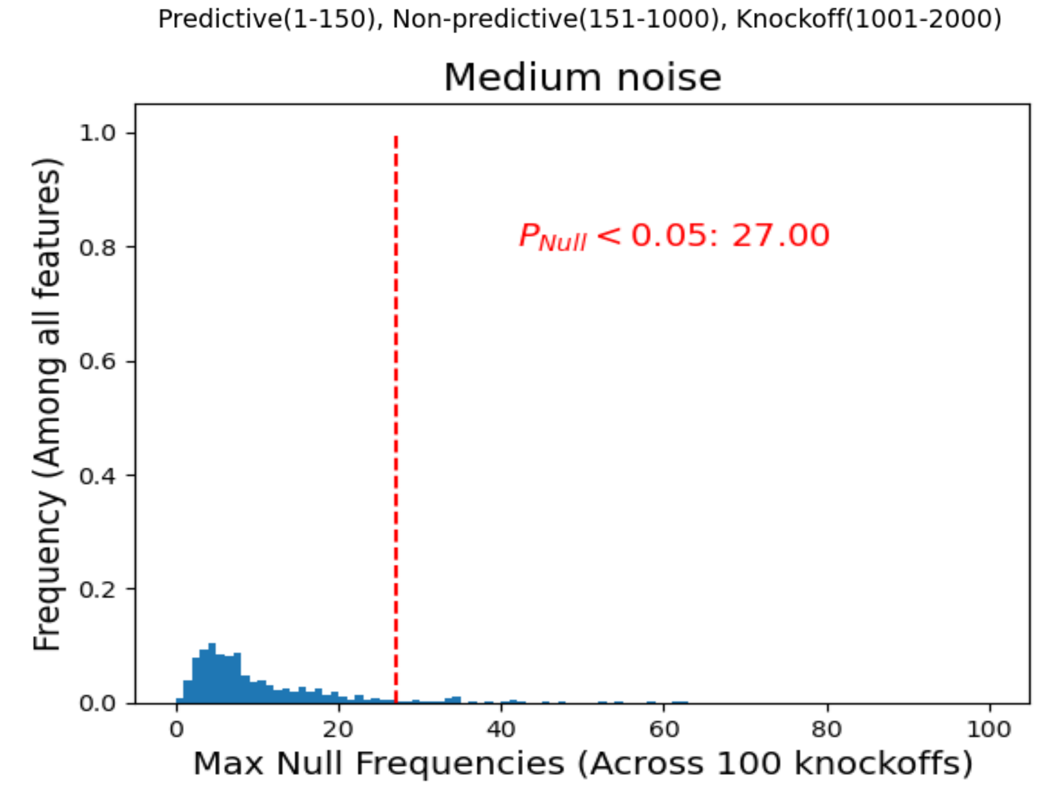
FPR < Threshold (0.05)?

$$\text{Estimated False Positive Rate (FPR):} \quad \frac{\#\ \text{Selected Knockoff}}{\#\ \text{All Knockoff}}$$

③ Further, to evaluate and avoid the selection noise in decoding, we applied a new false positive control method using permuted knockoff copies of original data to approximate false positive selection and reject dubious selected voxels for more reliable decoding. Estimated FPR plays the role as an additional iteration stopping criterion and controls FP.







④ By running the knockoff procedure with independently permuted copies we could then obtain the voxel-wise selection frequency across knockoffs. These frequencies reflect the selection stability. Knockoff procedure using null data provides observations of null selection. The max null selection frequency distribution facilitates the computation of a reliable frequency cutoff to control the probability of null (FP) selection at a desired low level.

Reference:

[1] Frisby, S. L et al. (2023). Decoding semantic representations in mind and brain. Trends in cognitive sciences, 27(3), 258-281.

[2] Lewis-Peacock, J. A., & Postle, B. R. (2008). Temporary activation of long-term memory supports working memory. Journal of Neuroscience, 28(35), 8765-8771.