Brain Decoding Using fMRI Data

Motor Baidoa

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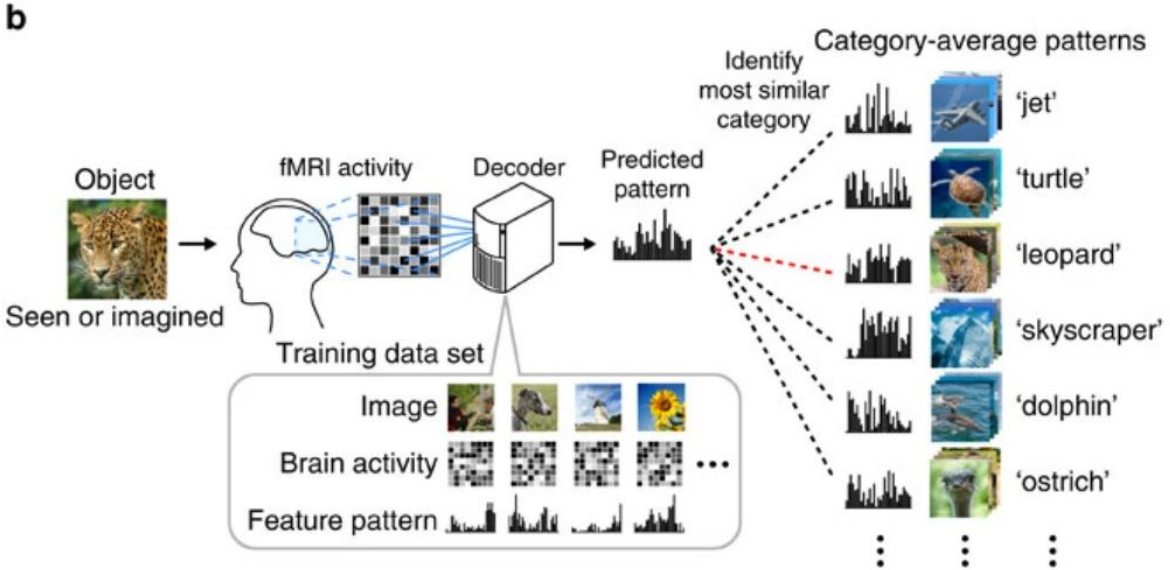
Introduction: Generic Object Decoding

We explore how the brain encodes sensory information by finding a relationship between stimuli and brain responses.



[Image Source]

Brain Activity

The brain is constantly active, processing information related to internal and external functions.

Involved ROIs

- **V1–V3 (LVC)**: *Basic Visual Features, Edge Detection, and Spatial Orientation*
- **V4 (MVC)**: *Color Discrimination and Shape Recognition*
- **LOC (HVC)**: *Object Form Recognition and Identification*
- **FFA (HVC)**: *Face Detection and Recognition*
- **PPA (HVC)**: *Scene and Place Recognition*

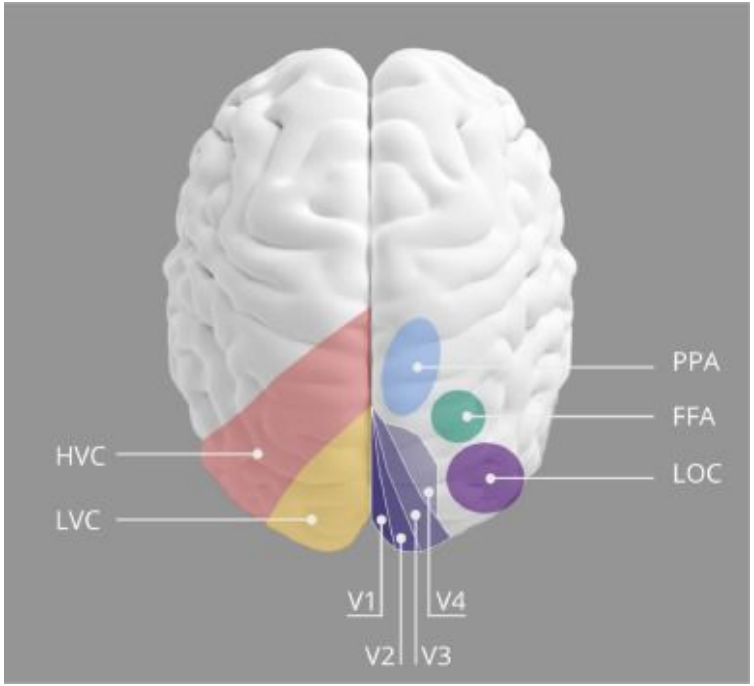


Image Source

Reproducibility Matters!!

Implementation Details:

- Numpy Random Generator Seed: 0
- Scikit Learn Random State: 7
- Test Ratio: 30%
- K-Fold: 5 folds (no stratifying, no shuffling)
- Applying Cross Validation on the Training Data to tune the parameters and test using Unseen Testing Data

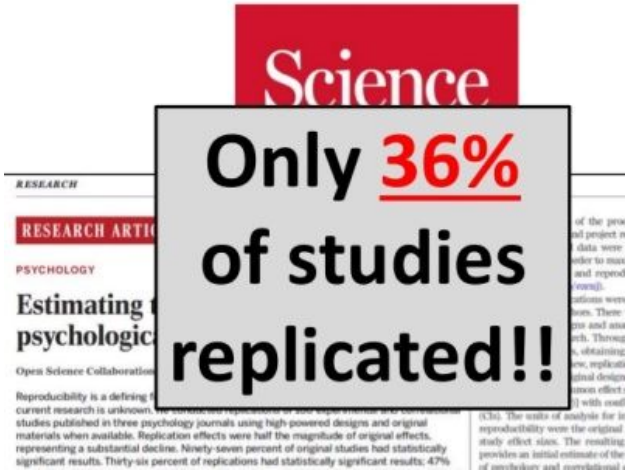


Image Resource

What are support vector machines (SVMs)?

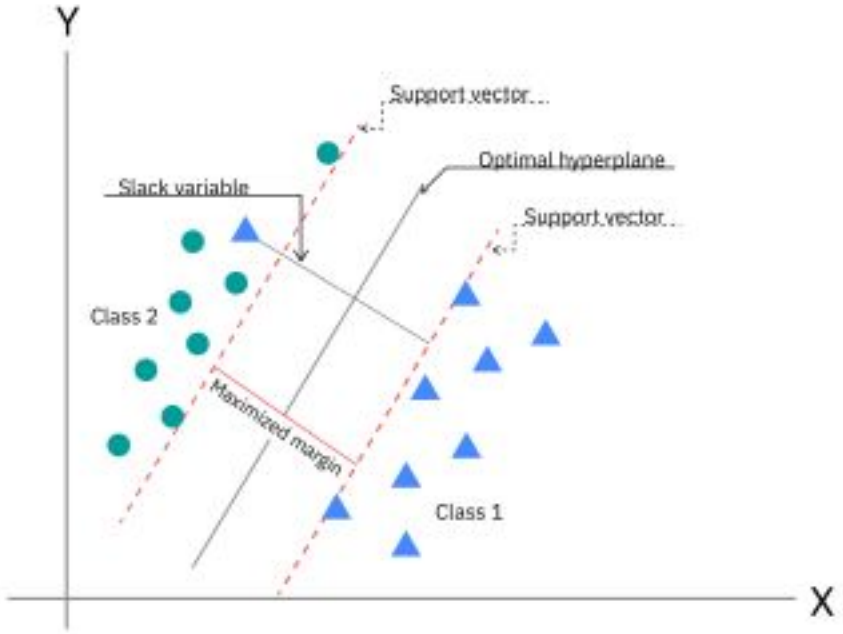
A support vector machine (SVM) is a supervised machine learning algorithm that classifies data by finding an optimal line or hyperplane that maximizes the distance between each class in an N-dimensional space.

Types of SVM classifiers:

1- Linear SVMs

2- NonLinear SVMs

3- Support vector regression (SVR)



Model Training and Evaluation using SVM

1- Dataset:

- Features and labels extracted from the `V3` ROI, processed for classification tasks.
- **Data Split:**
  - Utilized 5-fold Stratified Cross-Validation to ensure balanced class representation across folds.

2- Algorithm:

- **Support Vector Machine (SVM)**
- **Kernel:** Linear
- **Reason :**
  - A linear kernel is suitable for linearly separable data and offers interpretability.

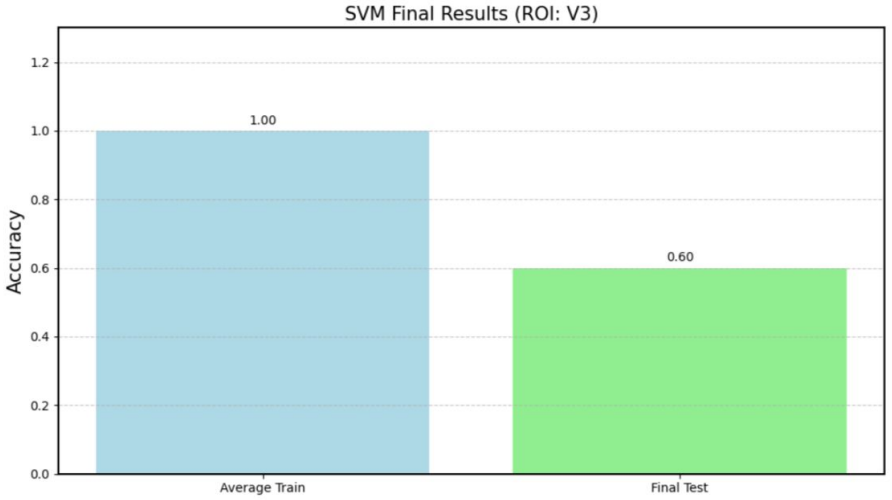
3- Cross-Validation Setup:

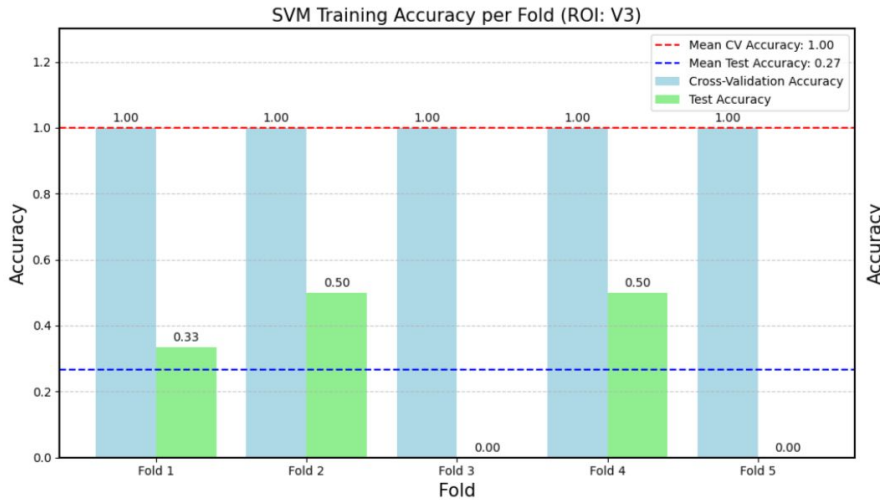
- **Cross-Validation Method:**
  - **K-Fold Cross-Validation** with `k=5` and `random_state=7`.

Model Training and Evaluation using SVM

4- Results:

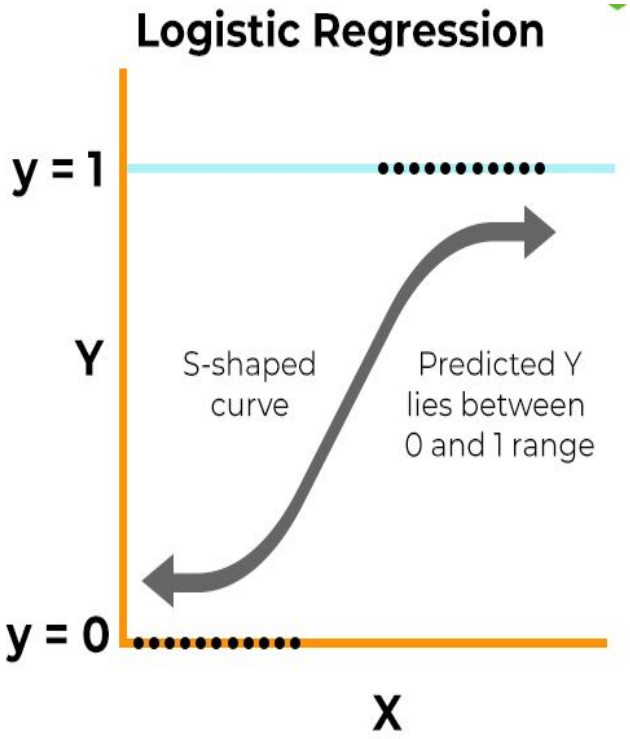
- **Performance Metrics:**
  - **Accuracy:** Used as the primary metric for evaluating model performance.
  - **Mean Cross-Validation Accuracy:** Presented as a red dashed line.





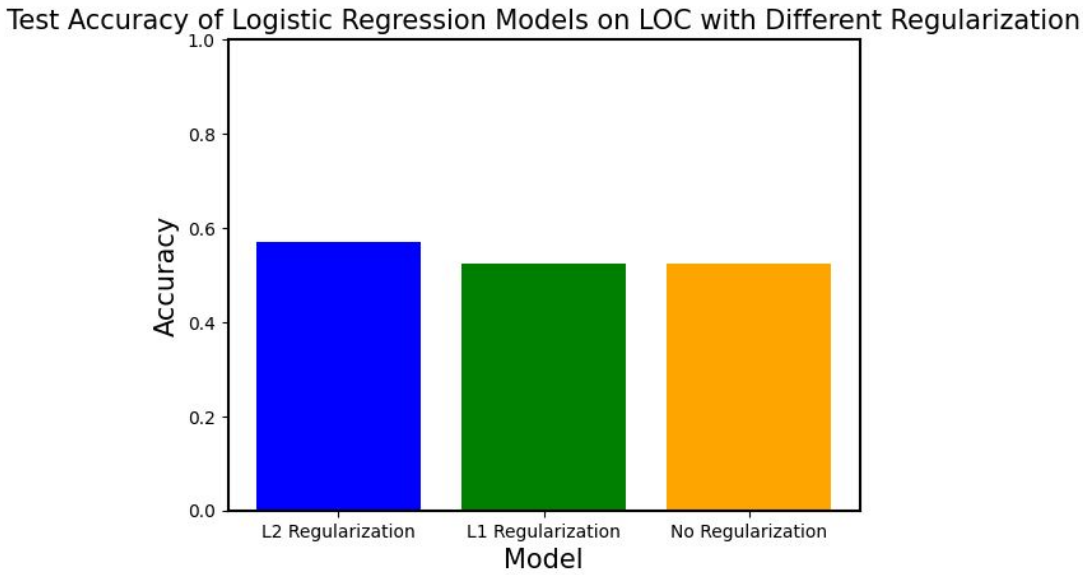
Logistic Regression (Regression & Classification at the same time).

- Binary output: logistic regression predicts probabilities between 0 and 1 useful for yes/no decisions
- S shaped curve: the model predictions follow an S shaped curve showing gradual shift from 0 to -1



Choosing the Best Regularization Technique

- Regularization as a method of overcoming overfitting.
- Which regularization technique yields higher accuracy?



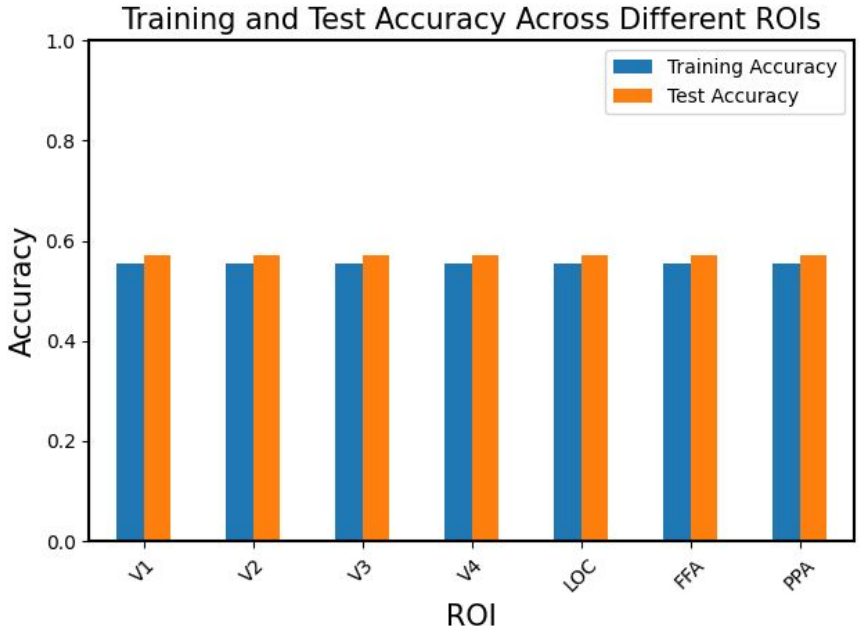
Logistic Regression: Evaluating the performance of classification models across different brain regions (ROIs)

Objective:

- Use Logistic Regression to classify brain activity across different Regions of Interest (ROIs).
- Employ **5-fold Cross-Validation** to evaluate the model's performance.

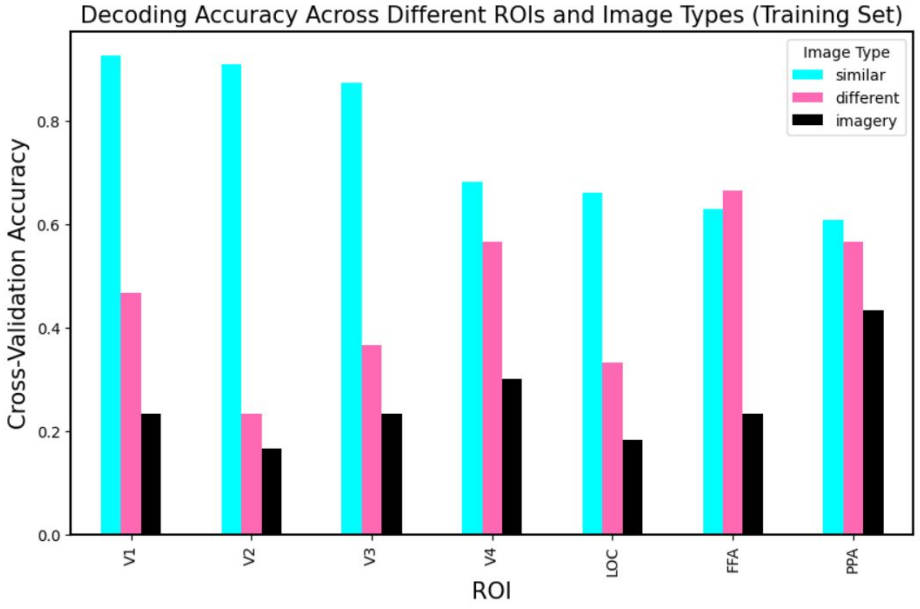
Table with the cross-validation results

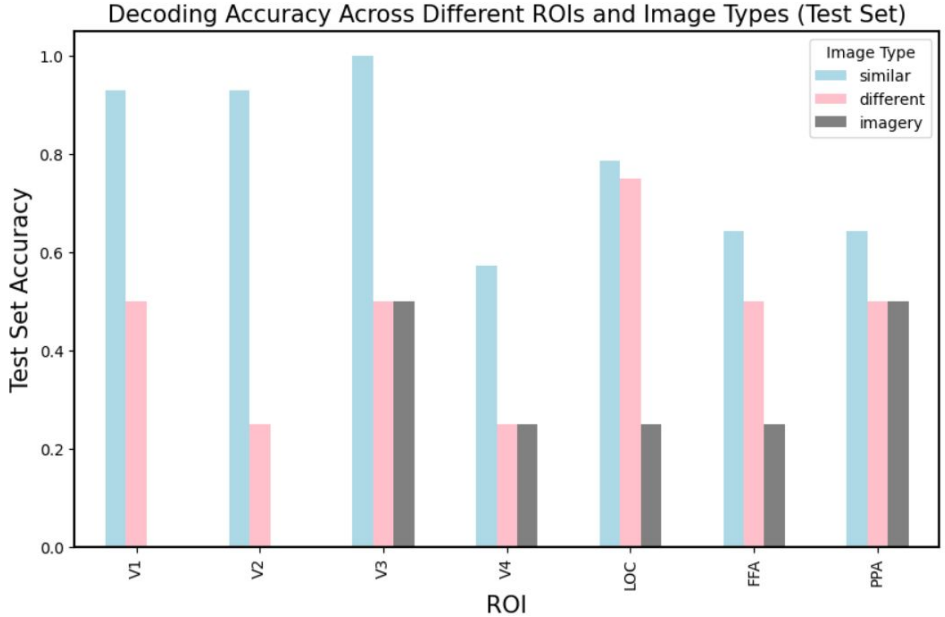
	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Mean Accuracy
V1	0.4	0.5	0.7	0.5	0.666667	0.553333
V2	0.4	0.5	0.7	0.5	0.666667	0.553333
V3	0.4	0.5	0.7	0.5	0.666667	0.553333
V4	0.4	0.5	0.7	0.5	0.666667	0.553333
LOC	0.4	0.5	0.7	0.5	0.666667	0.553333
FFA	0.4	0.5	0.7	0.5	0.666667	0.553333
PPA	0.4	0.5	0.7	0.5	0.666667	0.553333



Logistic Regression: Decoding model accuracy across different ROIs & image types using cross-validation

- Variations across ROIs
- Imagery-induced brain activity has the lowest accuracy overall.





Future work

- Using Neural Networks as decoders (capturing complex relationships), a relevant literature.
- Experimenting Using wider images categories (the challenge of generalization).
- Further working on enhancing the accuracy of ‘imagery’ task.
- Validating the results using statistical methods like: Hypothesis Testing Methods.
- Performing the study on more subjects, not only one (group level analysis).

Reference:

Horikawa, T., Kamitani, Y. Generic decoding of seen and imagined objects using hierarchical visual features. Nat Commun 8, 15037 (2017). https://doi.org/10.1038/ncomms15037

Thank you for your attention!

Any Questions?