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Familiarity Classification from Neuronal Spike Trains

BINARY CLASSIFICATION OF STIMULUS FAMILIARITY BASED ON NEURAL FIRING PATTERNS.

Project Overview

- Our goal is to predict if a stimulus is familiar or unfamiliar using neural data.
- We analyze 800 experiments of neuronal activity with specialized machine learning models

Methodology – Data Preprocessing

Raw Data Collection

X.shape = (800, neurons, timesteps)

y.shape = (800,), binary labels

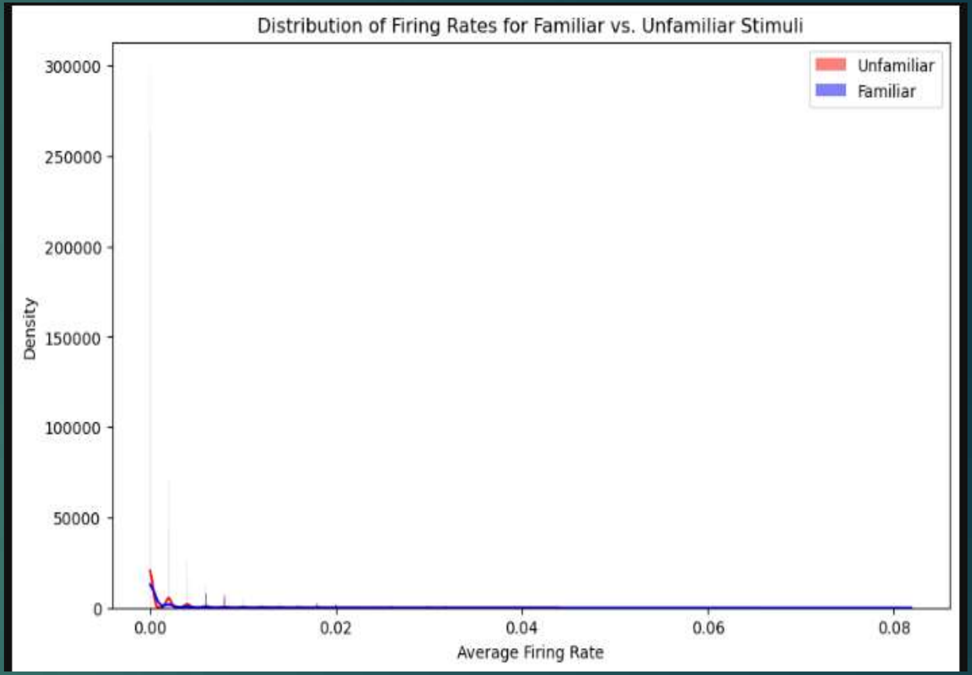
Feature Extraction

Average firing rate per neuron

Spike synchrony via correlations

Statistical Analysis

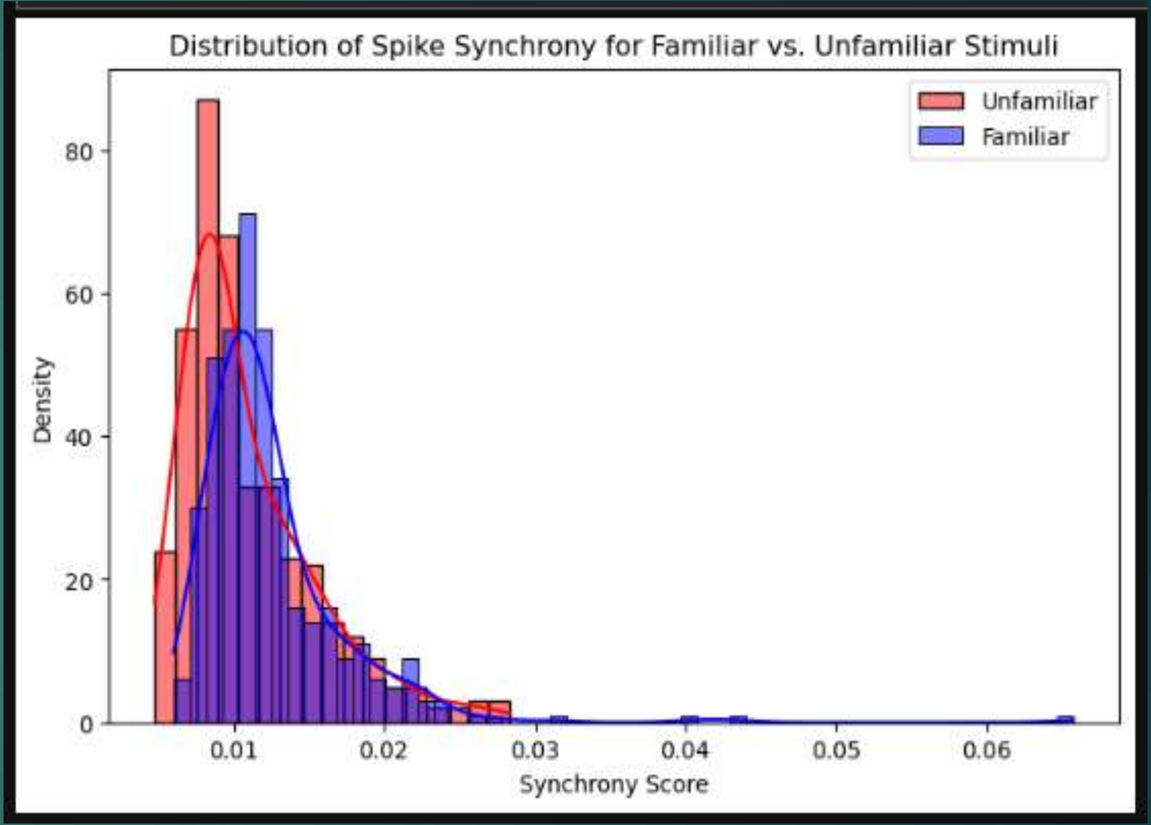
Inter-Spike Interval statistics (mean, std, CV)



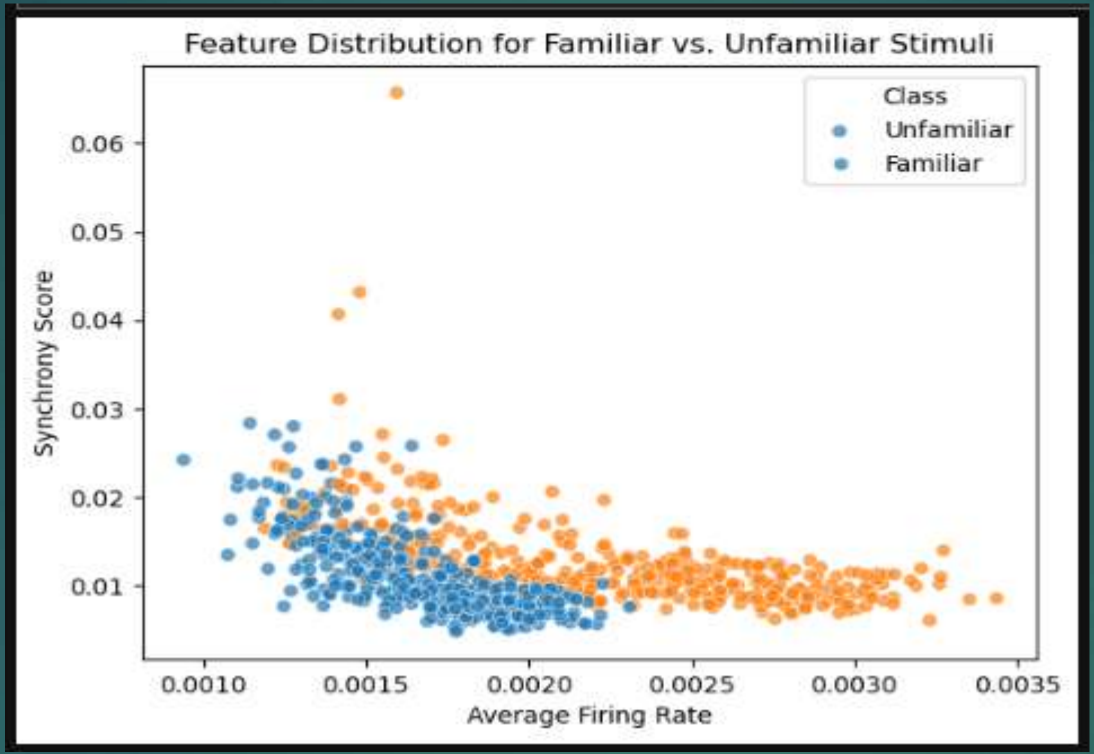
Exploratory Analysis

- **Distribution Analysis**
  - Histogram plots
  - Kolmogorov-Smirnov test
- **Effect Size Measurement**
  - Cohen's d calculation
  - Medium to large effects observed

- **Key Findings**
  - Significant differences between conditions
  - Clear statistical separation



Feature Space Visualization



2D	800	2
Dimensions	Data Points	Classes
Firing Rate vs Synchrony plot	Clear classification boundaries visible	Familiar and unfamiliar stimuli

Classification Models

Random Forest
Handles feature interactions well
Captures nonlinear patterns

Logistic Regression
Linear decision boundary
Interpretable baseline model

SVM
RBF kernel for nonlinear boundaries
Effective with limited features

Model Evaluation Metrics

Accuracy

Measures overall performance across all predictions

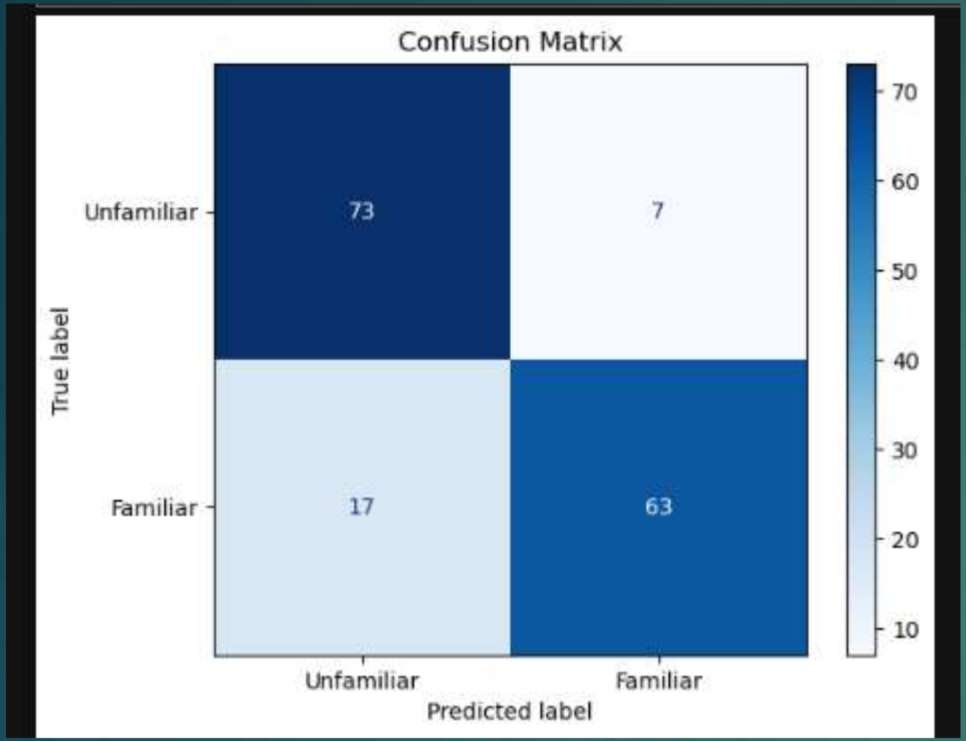
F1-Score

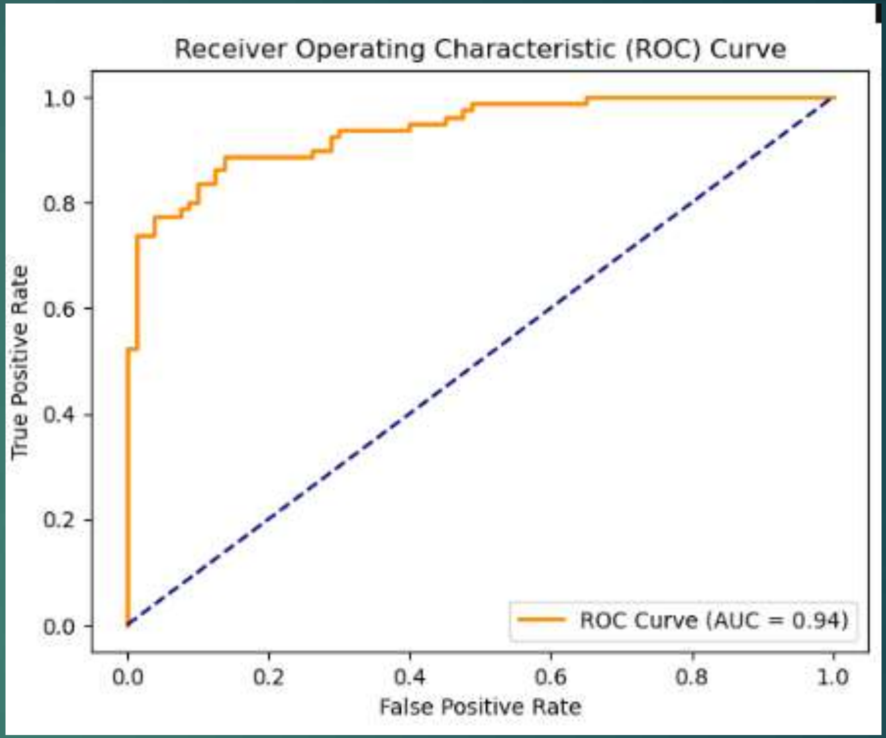
Balances precision and recall for both classes

AUC - ROC

Evaluates probabilistic ranking of predictions

Model Evaluation

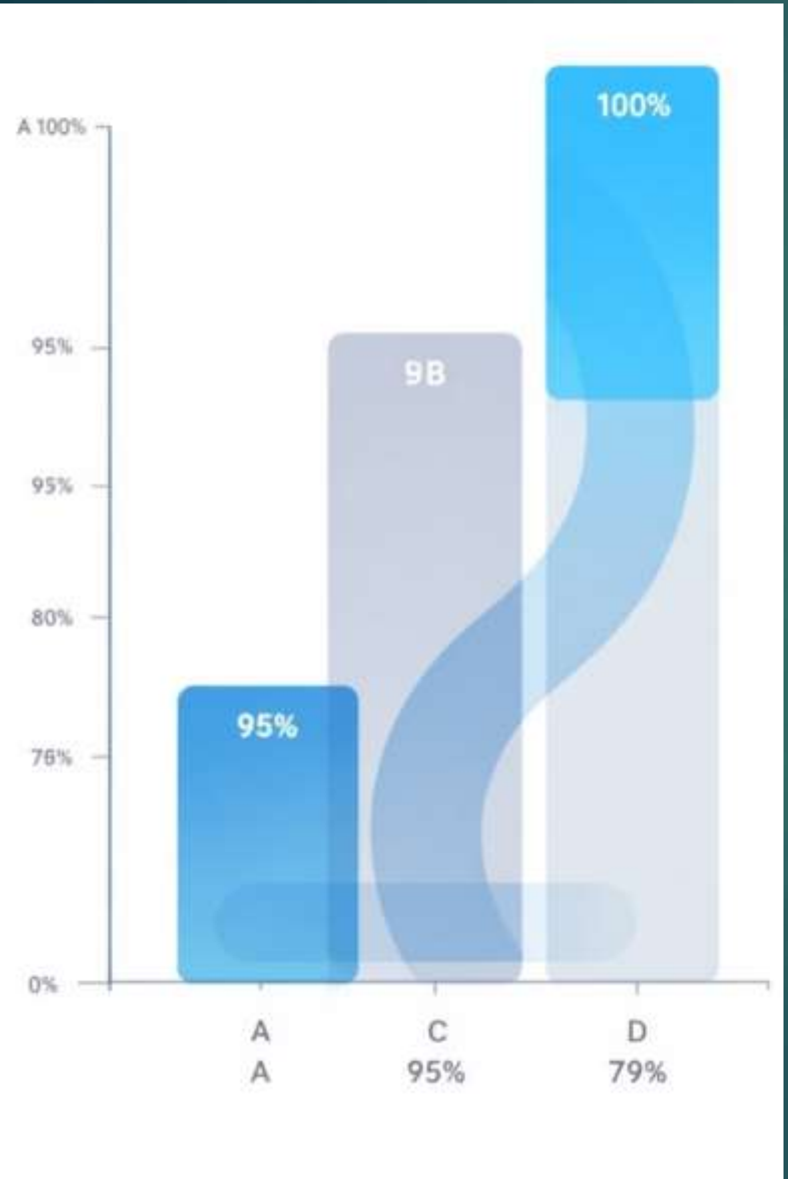




Confusion matrix showing spike train classifier accuracy: The model distinguishes 'Familiar' vs 'Unfamiliar' stimuli with 85.5% accuracy, showing stronger performance in detecting unfamiliar patterns

ROC curve indicating high model performance with AUC = 0.94, reflecting strong discrimination between familiar and unfamiliar spike train patterns.

Model Comparison



Feature Set	Model	Accuracy	F1 Score	AUC
Firing Rate Only	Logistic Regression	0.70	0.71	0.75
Synchrony Only	SVM	0.72	0.73	0.77
ISI Features Only	Random Forest	0.74	0.74	0.78
All Combined	SVM	0.78	0.79	0.83

Reliable Classification of Familiar vs. Unfamiliar Stimuli

- Achieved **78% classification accuracy**.
- Confusion matrix shows high **true positives (63)** and **true negatives (73)**.
- **Firing rate** and **synchrony** showed significant differences ($p < 0.05$).
- Confirms that neural firing patterns **reliably encode stimulus familiarity**.

The strong performance in both familiar and unfamiliar conditions suggests stable encoding mechanisms across trials

ISI Features Reveal Critical Temporal Coding

- **ISI-based features** captured fine-grained timing patterns beyond rate alone.
- Timing dynamics contribute uniquely to the model's performance.
- Highlights the importance of **temporal structure in neural encoding**.
- Supported by clear separability in ISI feature distributions.

Emporal structure in spike trains plays a key role in neural coding, beyond what static rate measures reveal.

Multivariate Features Improve Classification Accuracy

•**Random Forest with all features** achieved the **highest AUC (0.83)**.

•Performance improved with **richer feature sets**.

•Distribution plots showed clear class separability across features.

•Confirms that **no single feature is sufficient** — integration is key.

The results validate a multivariate decoding approach, leveraging both spatial and temporal neural dynamics.

Real-World Relevance and Future Applications

•Method generalizes to other **perceptual learning** and neural decoding tasks.

•Results suggest **potential for real-time application** in brain-computer interfaces.

•Validates **feature engineering** as a practical strategy for decoding neural activity.

•Offers a framework for expanding spike train analysis in **adaptive systems**.

This work lays the groundwork for robust neural classification pipelines applicable beyond the current study.

Summary & Interpretation

•Neural features can accurately classify stimulus familiarity (78% accuracy, AUC 0.94).

•Temporal and multivariate features significantly enhance model performance.

•Results support the importance of both rate and timing in perceptual coding.

•Interpretation: Encoding of stimulus familiarity is distributed across multiple neural features and time scales.

Thank you! ☺