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The modeling of state-dependent memory with artificial intelligence approaches

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Introduction

State-dependent memory (SDM) is the term that explains recalling particular information occurs most accurately when a subject (humans or animals) is in the same physiological state of consciousness as it was at the time of memory formation. One way of evaluation of memory consolidation and retrieval is the Passive-Avoidance Task (Figure 1).

Figure 1. Passive Avoidance Task, Step-through

It is a fear-aggravated test used to evaluate learning and memory in rodent models of CNS disorders. The present study was defined to construct an accurate model that predicts memory formation under drug abuse. The model assists scientists in the field to appraise their new hypotheses and inspire for further experiment-design without neither animal usage nor a colossal amount of time consumption.

Methods

The primary dataset for the present modeling was generated by combining the data extracted from five pieces of our previous researches (published in neuroscience journals) that elucidated the influences of various states of consciousness in memory retrieval. Throughout these studies, multiple drugs including morphine, nicotine, MDMA, ethanol, mecamylamine, S-WAY100135 (an 5-HT1A receptor antagonist), ACPA/AM251 (cannabinoid CB1 receptor agonist/antagonist), WIN 55,212-2 (a cannabinoid CB1/CB2 receptor agonist) and dextromethorphan were injected into the different brain sites during post-training and/or pre-test phases of passive avoidance learning task to measure memory consolidation or retrieval in male Wistar rats. Each row in the data-set represented a single experiment on an animal that a combination of drugs with specific doses was administered via systemic or intracerebral injections. The last column of each row was the latency of the passive avoidance task in the range of 0 - 300 seconds to assess memory retrieval based on injections' combination. Trials were randomly split into train-set and test-set with a portion of 0.8-0.2; correspondingly, the models were fed with the train-set. The following machine-learning algorithms were applied to establish the most accurate model to predict the latency of the passive avoidance task:

- Linear Regression
- Support-Vector Machine
- Decision Tree
- Random Forrest
- K Nearest Neighbors (KNN)
- Neural Networks

The hyper-parameters of every utilized algorithm were tuned by using grid-search functions and illustrative plots.

Results

The best performance of a model was observed in a compound voting model that returned the mean value of latency output from "Support-Vector," "Decision Tree," "Random Forrest," and "K-Nearest Neighbors" regressors (Figure 2).

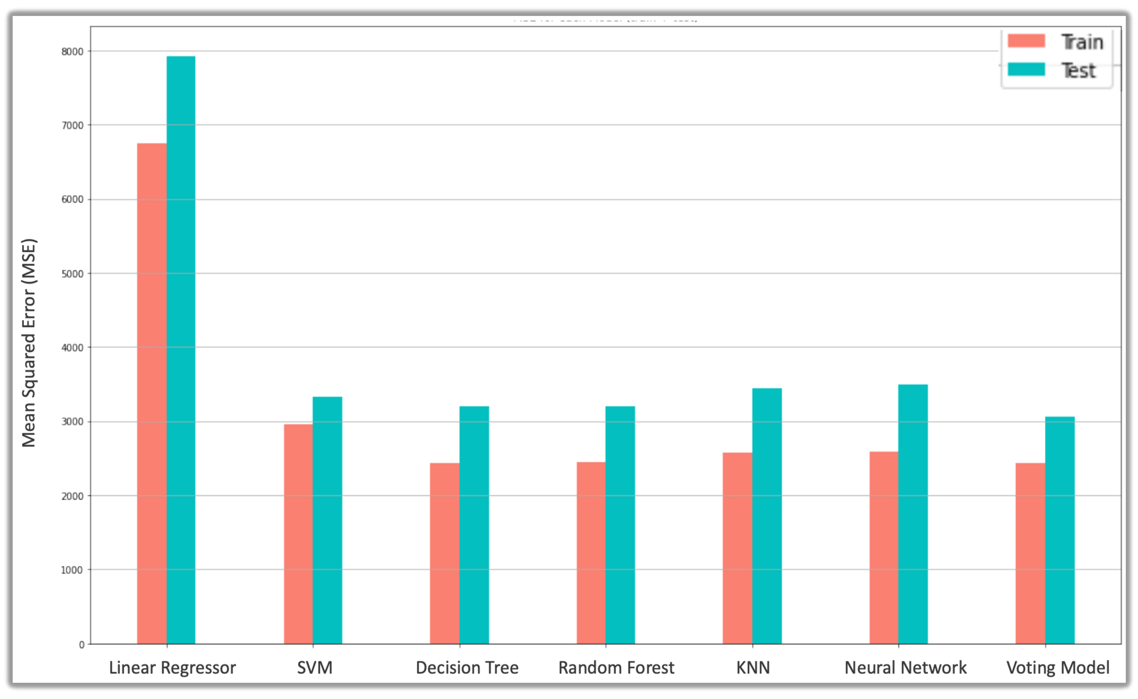

Figure 2. Comparison of the mean squared error in the models separated by train-set and test set

The voting model attained the R2-score of 0.803 on the train-set and 0.781 on the test-set. Moreover, the model reached the Root-Mean-Squared-Error (RMSE) of 49.36 on the train-set and 55.39 on the test-set for predicting the latency of passive-avoidance learning task (Table 1).

	RMSE	R2 Score
Validation-set	49.36	0.803
Test-set	55.29	0.781
Random Predicts	145.49	-0.513

Table 1. Voting Model Results

In addition, the plot which illustrates a comparison between real latency and the prediction of the compound voting model in test-set suggests the validity of the model (Figure 3).

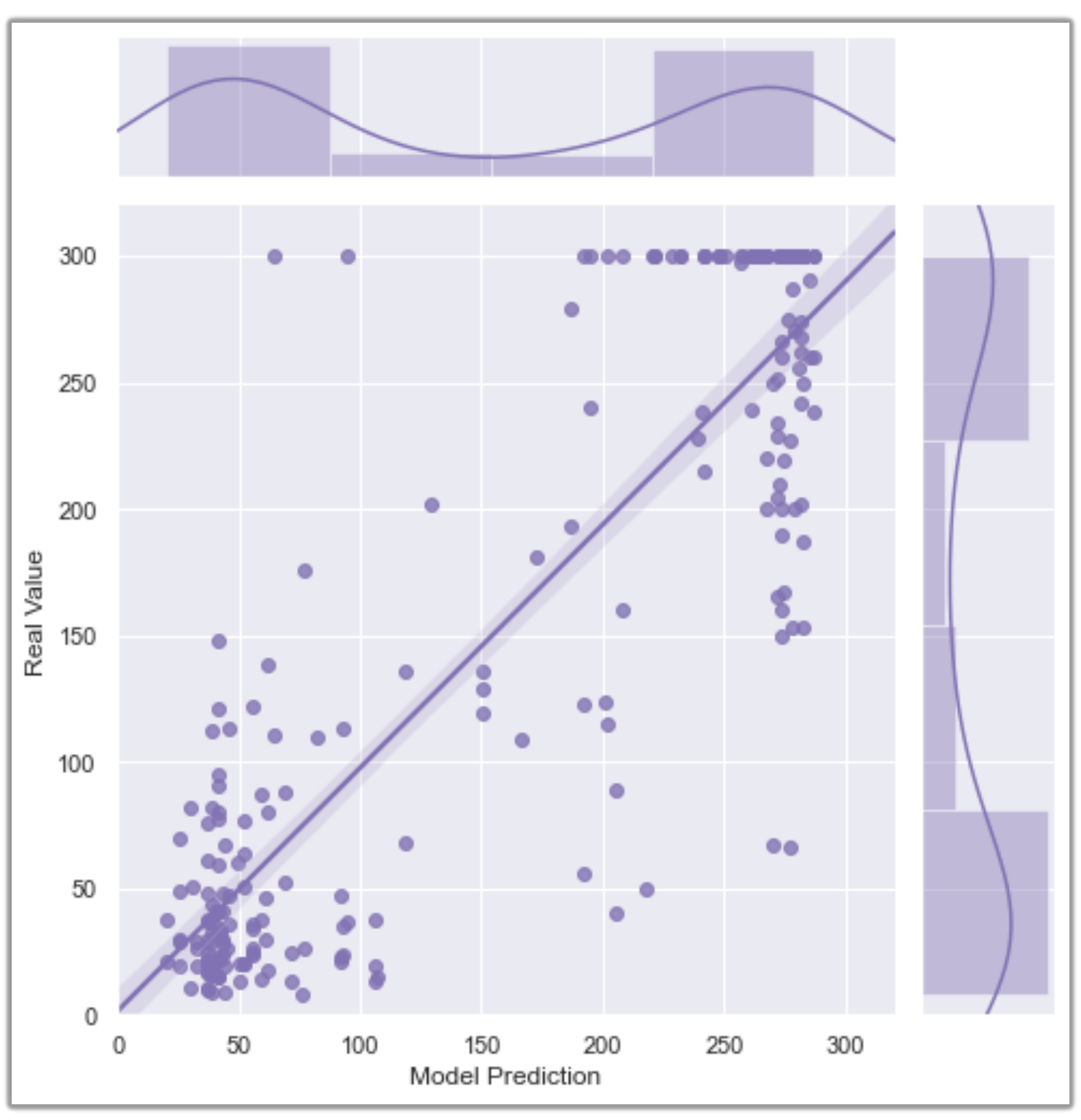

Figure 3. Comparison of the voting model predictions on latency values with equivalent real values

Discussion

Since the latency numbers can be inferred as a binary conclusion of amnesia or solid memory, and by assuming that latency of 150 seconds or less is referring to amnesia, the model has an accuracy of 93% in predicting amnesia or memory based on injections' doses (Table 2).

	Precision	Recall	F1-Score	Accuracy
Amnesia	0.93	0.92	0.92	-
Memory	0.93	0.93	0.93	-
Model	-	-	-	0.93

Table 2. Classification report with the assumption of 150th second as the category separator

It is noteworthy that although Neural-Networks usually perform perfectly through Machine-Learning modelings, the small dataset just caused overfitting without any help on test-set. On the other hand, models like decision trees performed much better in the study (Figure 4).

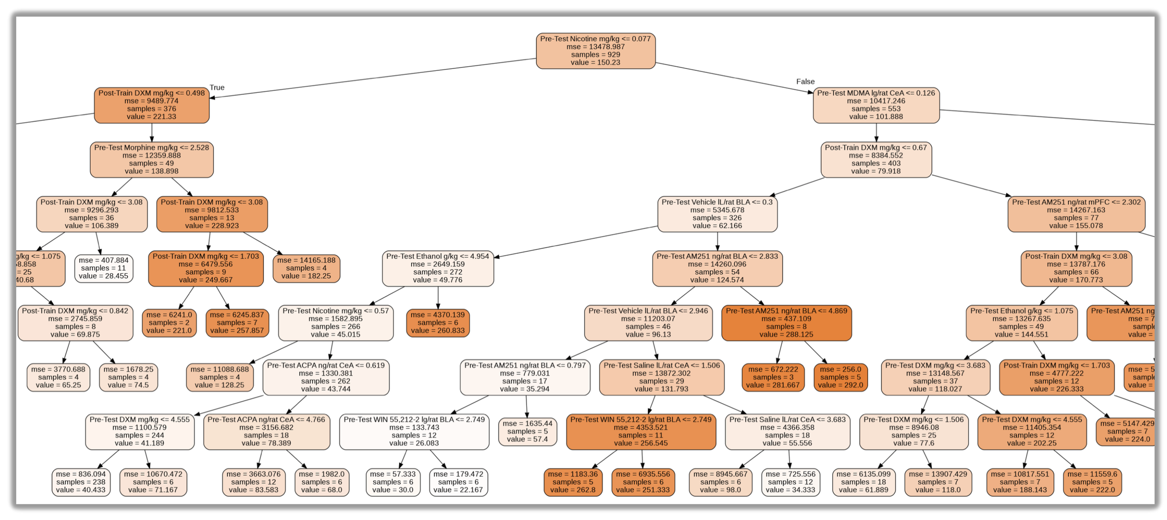

Figure 4. Part of the designed decision tree, max depth=8

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