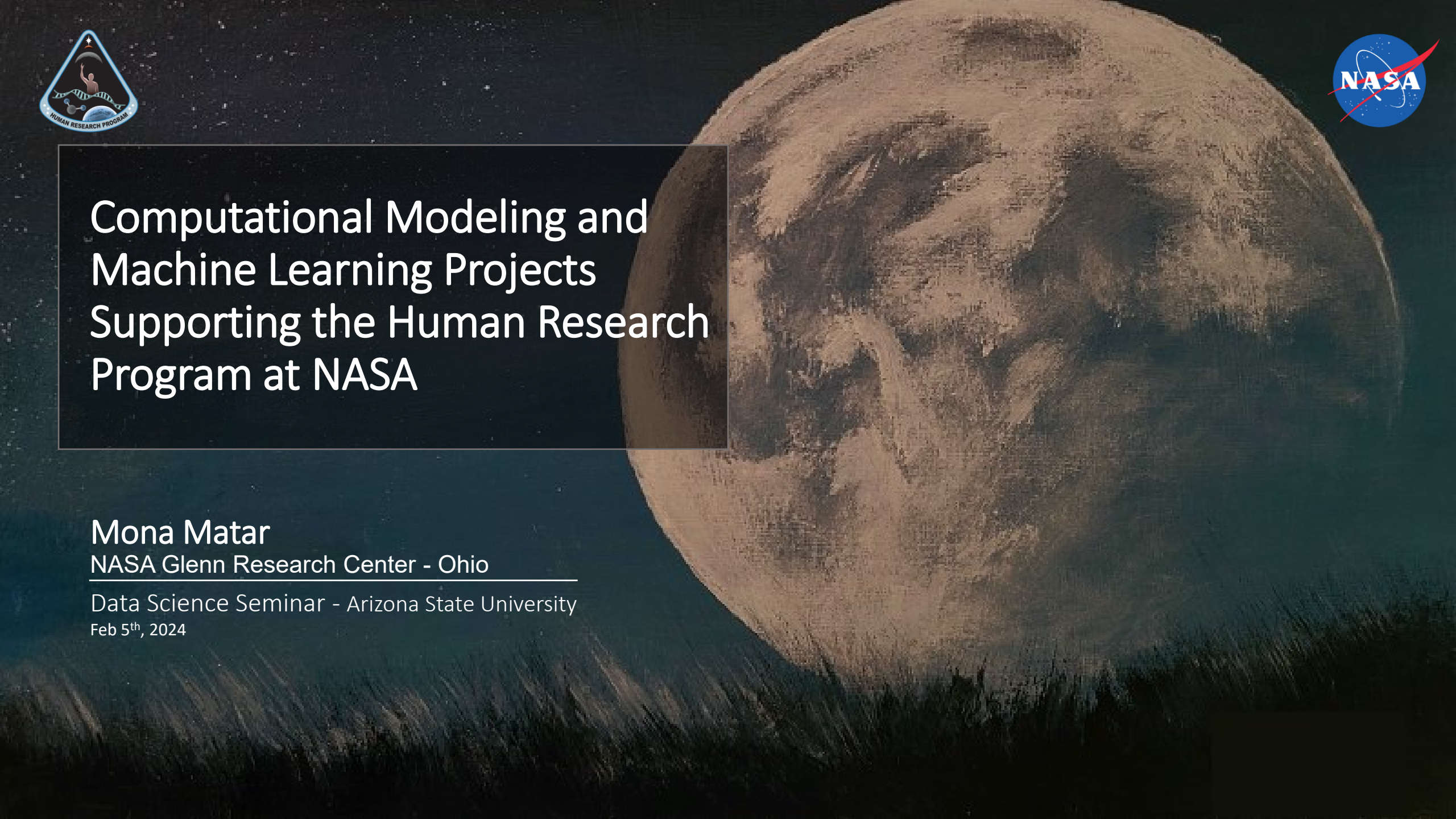


Computational Modeling and Machine Learning Projects Supporting the Human Research Program at NASA

Mona Matar

NASA Glenn Research Center - Ohio

Data Science Seminar - Arizona State University

Feb 5th, 2024

My Background

Education

Aug 2004
B.S. in Electrical and Electronics Engineering
focusing on Telecommunications and Computer Science
The Lebanese University

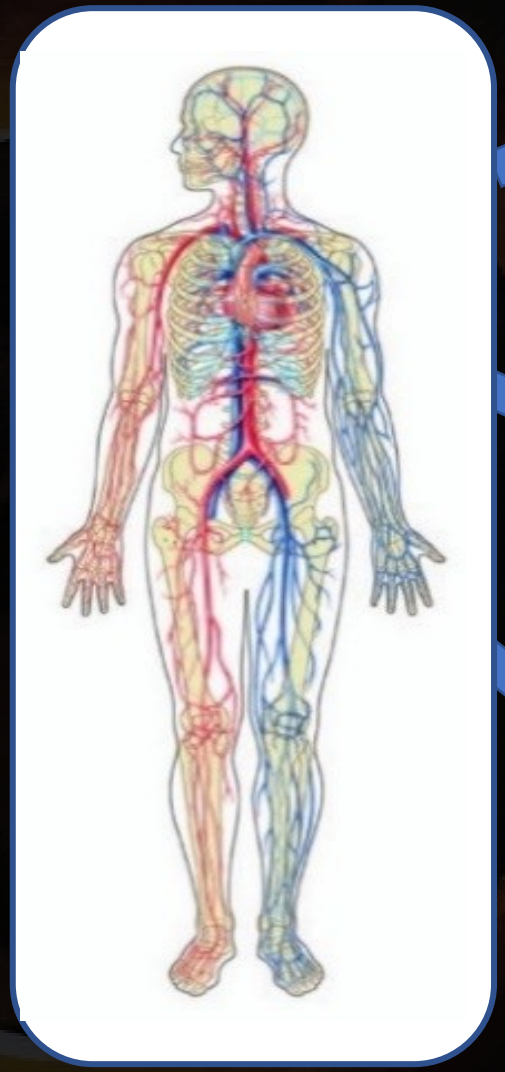
Aug 2014
Master in Applied Mathematics
The University of Akron
Thesis Title: Atomistic-To-Continuum Modeling Of The Detachment Of A Graphene Sheet

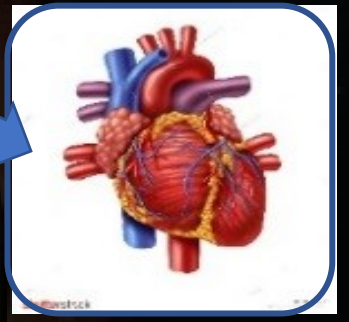
Aug 2019
Ph.D. in Applied Mathematics
Kent State University
Dissertation Title: Node and Edge Importance in Networks via the Matrix Exponential

Projects at Glenn Research Center

Projects for the Human Research Program

- Crew Health and Performance – Probabilitic Risk Assessment (CHP-PRA)
- Spaceflight Associated Neuro-ocular Syndrome (SANS)
- Renal stones
- Operational Volume Data and Habitat Design





Tools and Models

- Simple regression (Data driven, curve fits)
- Multifactorial regressions (Data driven, Gaussian Process Regression, Neural Networks)
- Probabilistic inference (Bayesian networks)
- Event tree structure
- Deterministic model
- Probabilistic model
- Hybrid models

Possible Data Sources

Ground studies

Animal

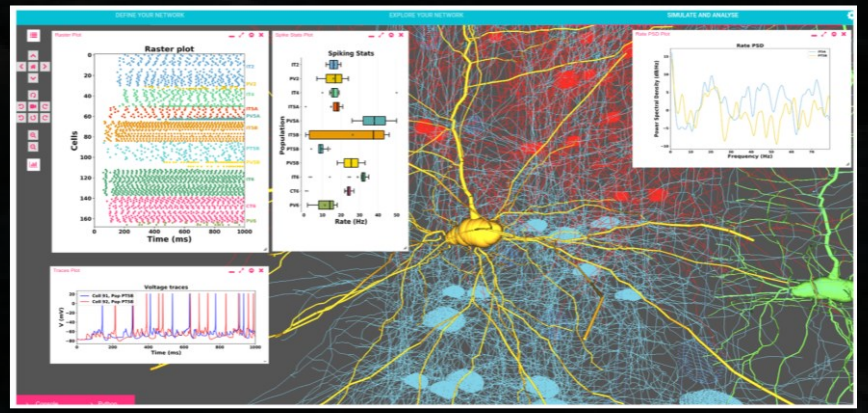
Human

Astronaut data

NEURON
for empirically-based simulations

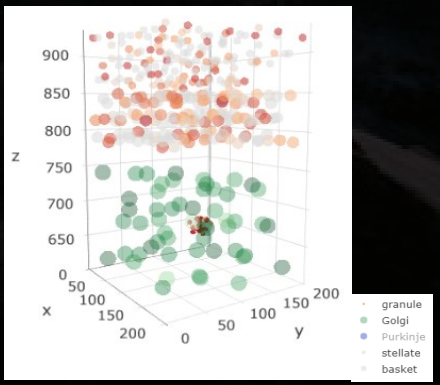
NetPyNE

NetPyNE GUI



Courtesy: http://www.neurosimlab.com/netpyne/overview.html

Cerebellum microcircuit



COLLABORATORY

CBS Project

Alien Brain Study

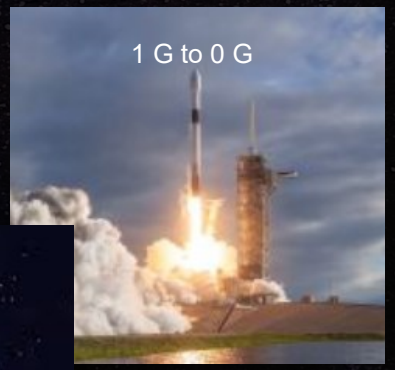
CBS Project

Radiation exposure

Galactic Cosmic Rays (GCR)

Solar Particle Events (SPE)

Altered gravity



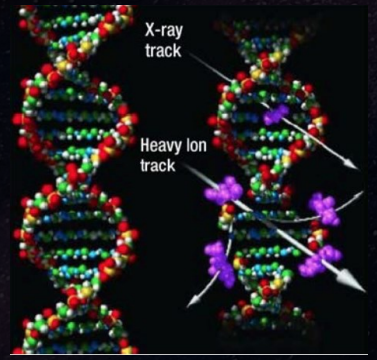
Isolation / confinement

CBS Project

Central nervous system

Altered cognitive function

DNA molecule can break



Behavioral medicine

Depression
Fatigue
Circadian rhythm
Monotony
Boredom
Hallucination
Anxiety

Sensorimotor

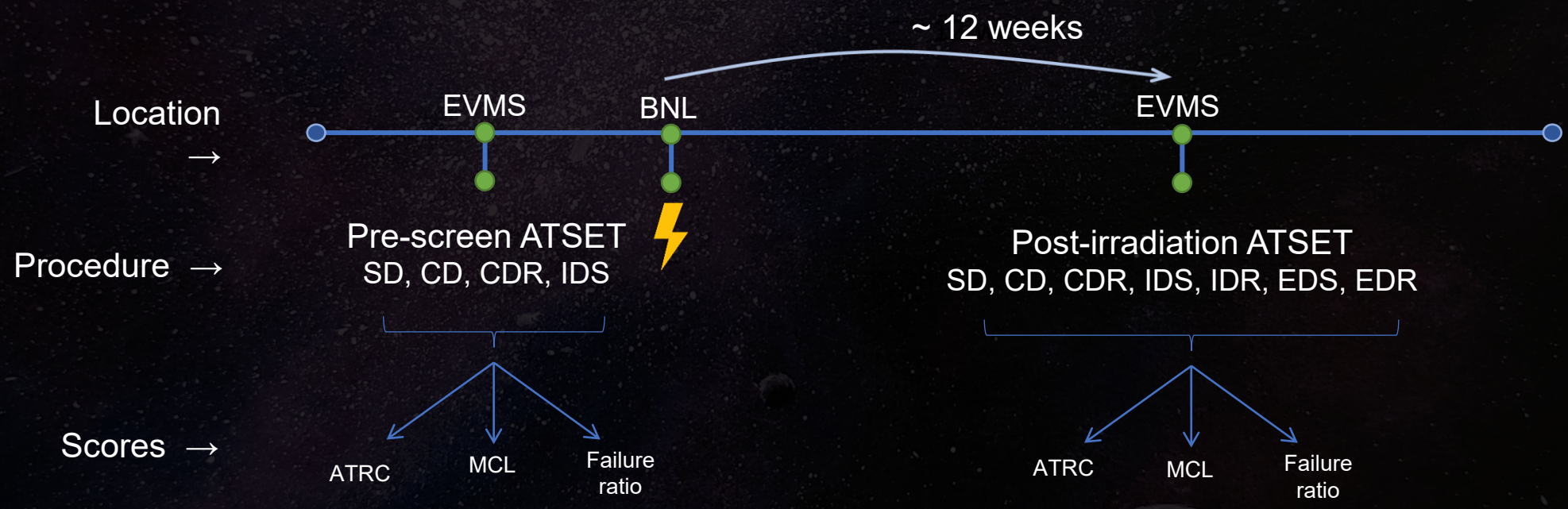
Spatial orientation
Space motion sickness
Difficulty walking

Tools and Models

- Subjects are Wistar rats
- ATtentional SET shifting test
- Cognitive flexibility performance
- Series of 7 stages: SD, CD, CDR, IDS, IDR, EDS, EDR
- Different relevant/irrelevant cues in each stage
- Criterion to pass: 6 consecutive successful attempts
- Experiment by Dr. R. Britten's lab (Jewell et al., 2018; Britten et al., 2020; Burket et al., 2021)

ATSET: ATtentional SET shifting test
SD: Simple Discrimination
CD: Compound Discrimination
CDR: Compound Discrimination Reversal
IDS: Intra-Dimensional Shifting
IDR: Intra-Dimensional Shifting Reversal
EDS: Extra-Dimensional Shifting
EDR: Extra-Dimensional Shifting Reversal

Experiment Timeline and Data



Objective

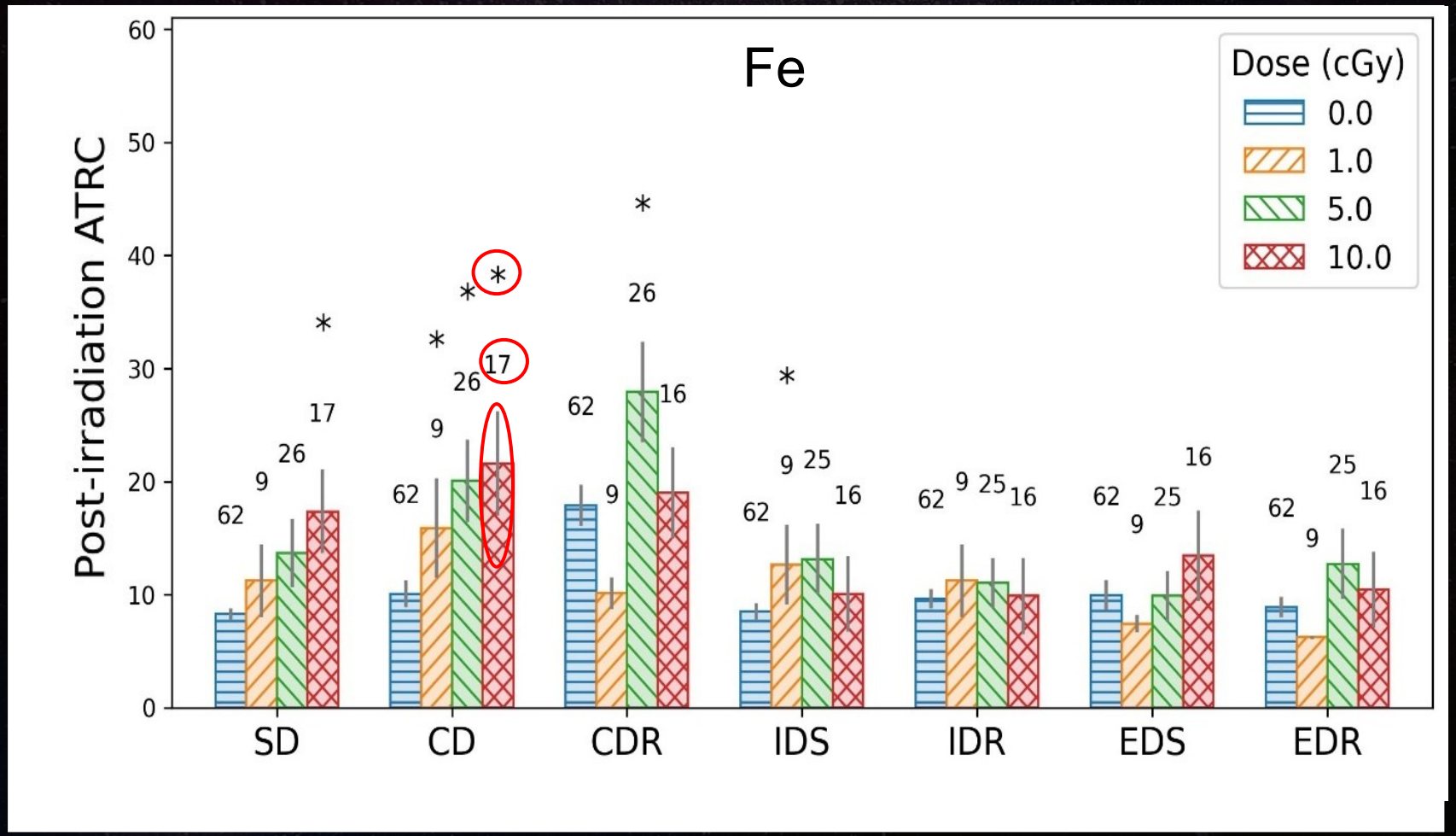
Predict cognitive impairment:

- at subject level
- based on prescreen scores

Implication for astronauts:

- probability of failing a task for each individual
- before spaceflight

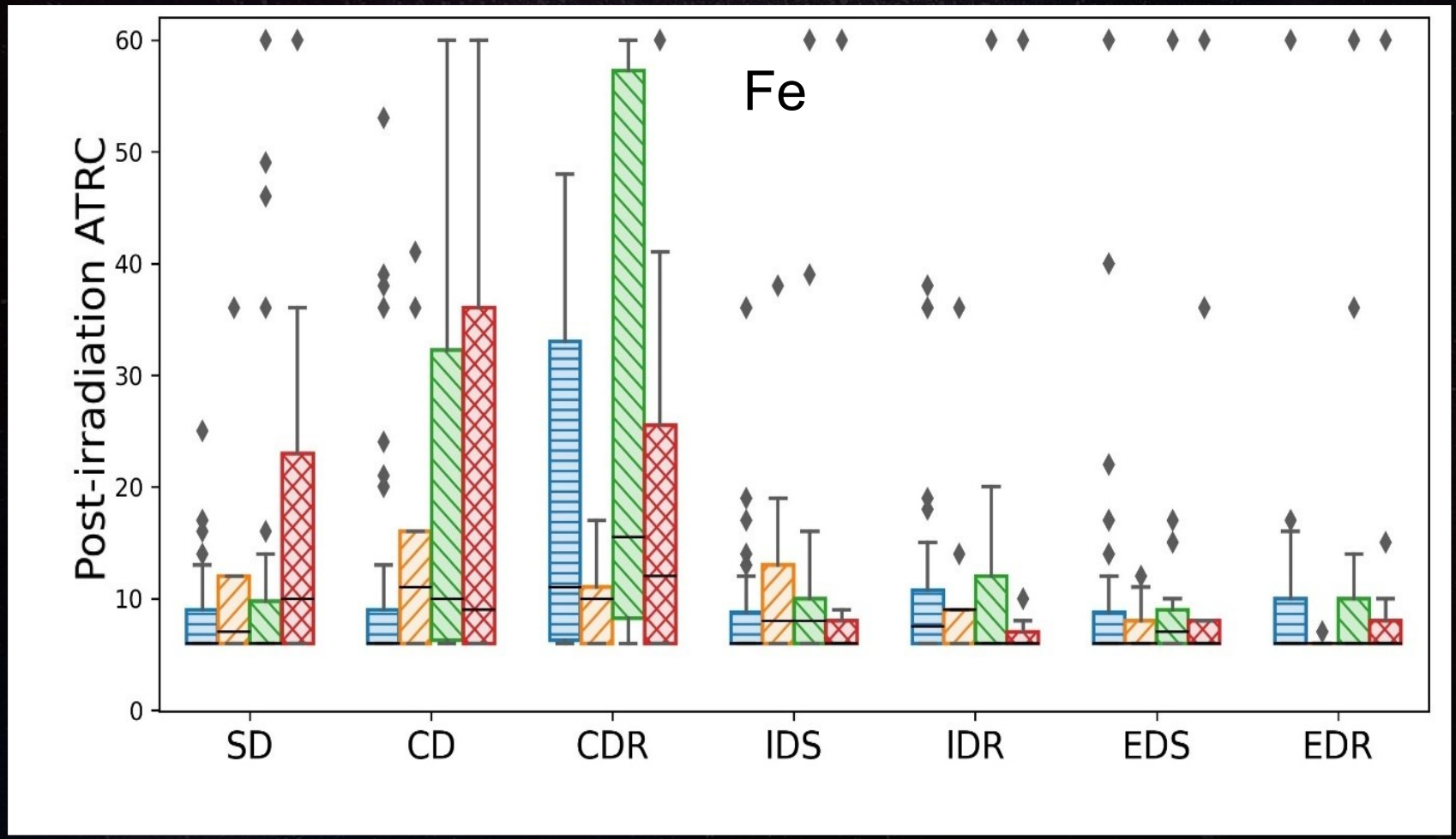
Basic Statistics



- "*" statistically different from control
- Group size above the bar
- Large SEM
- Δ in the number of rodents

Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.

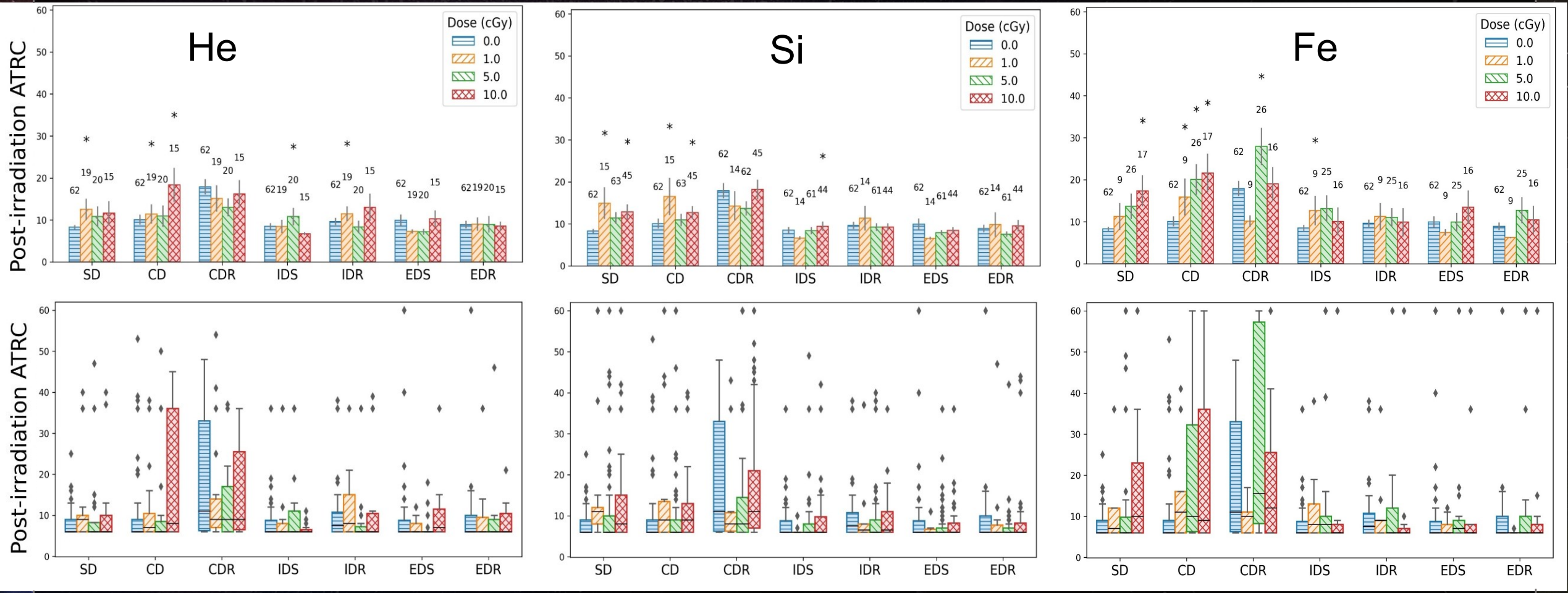
Basic Statistics



- Mean and SEM not representative of the distribution
- Many outliers shift the mean
- Data bimodal

Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.

Basic Statistics



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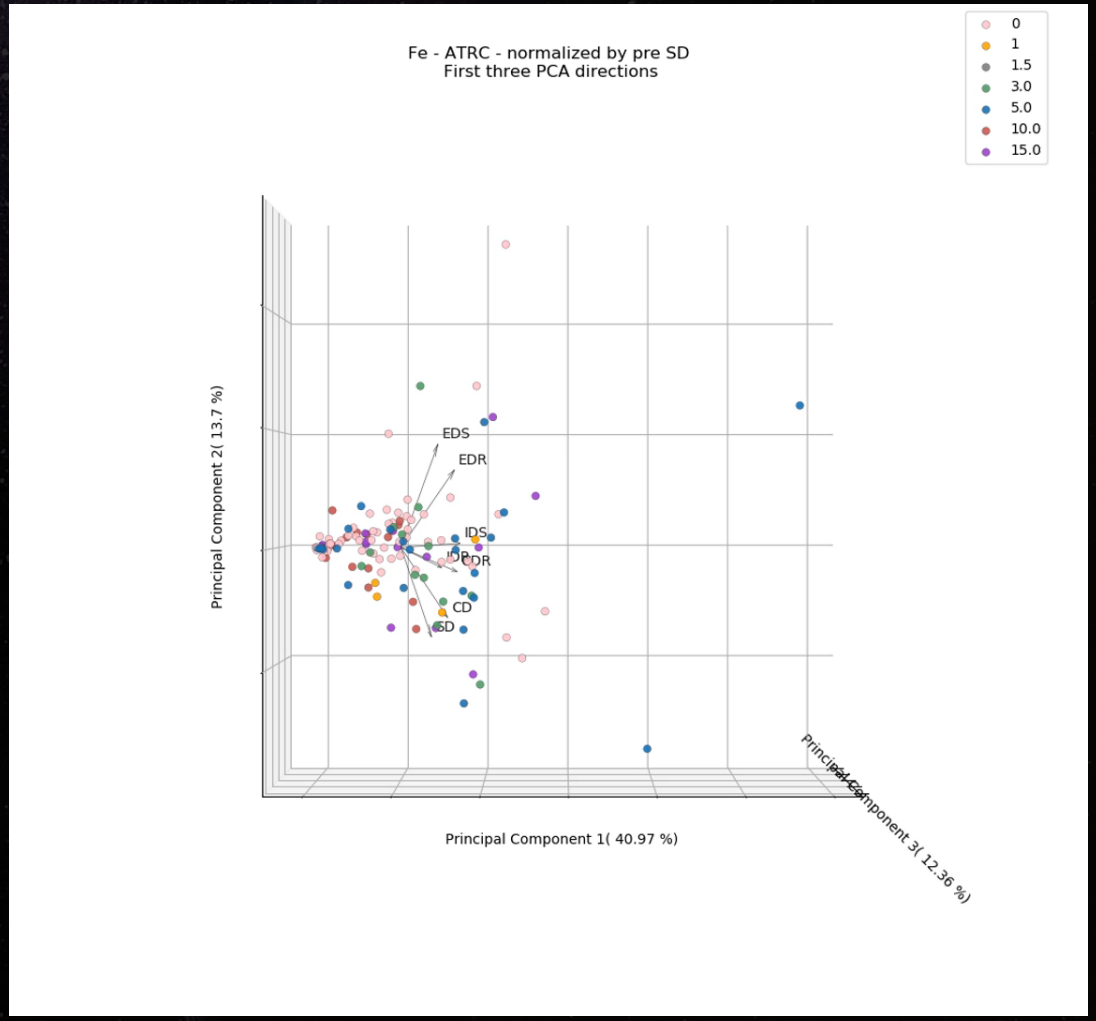
PCA Analysis

- PCA to reduce the dimension of the dataset and visualize the data
- Create a new coordinate system with orthogonal bases
- Projection of the data has greatest variance on the first component, then second, …
- Reduce the dimension by selecting the first few principal components

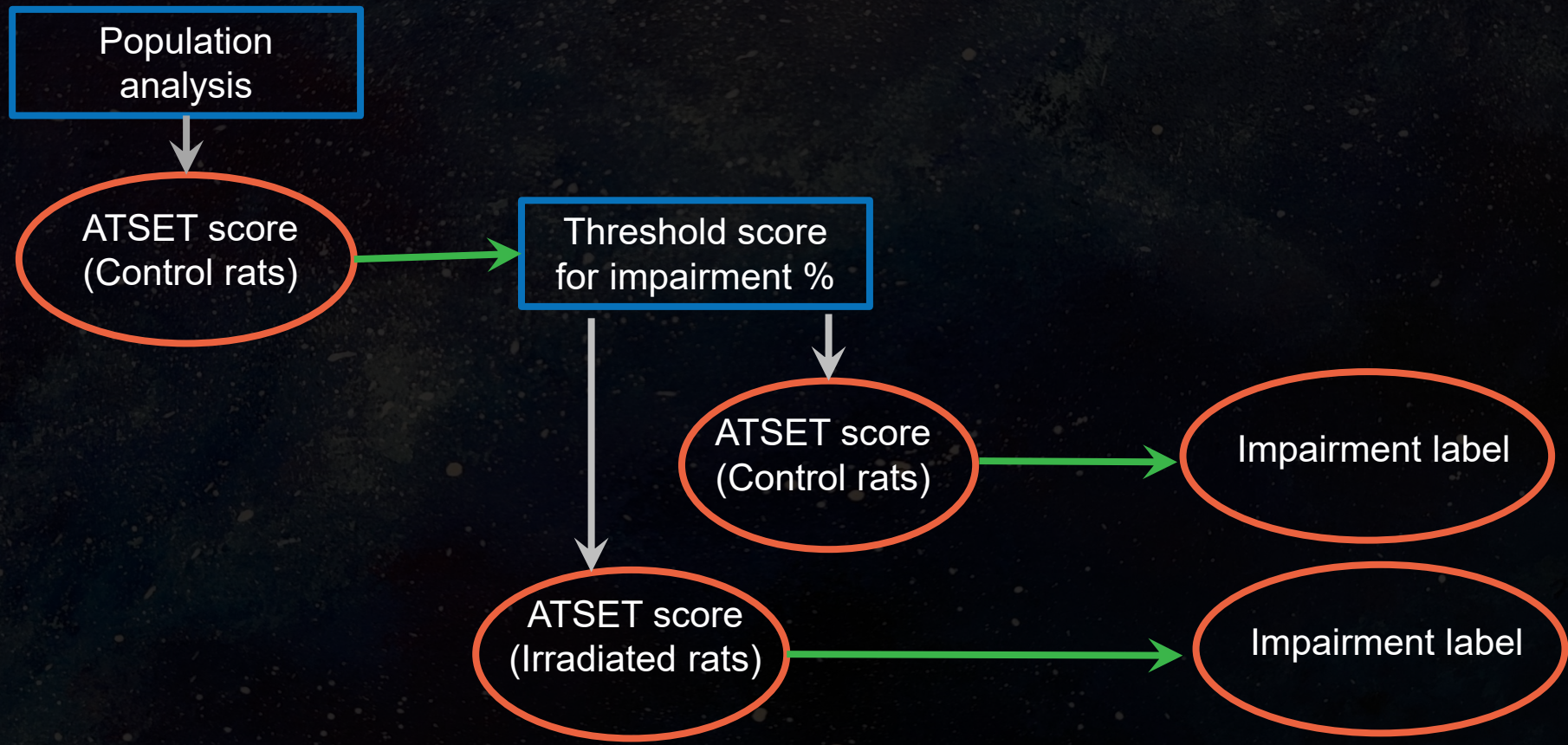


Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.

Supervised Machine Learning

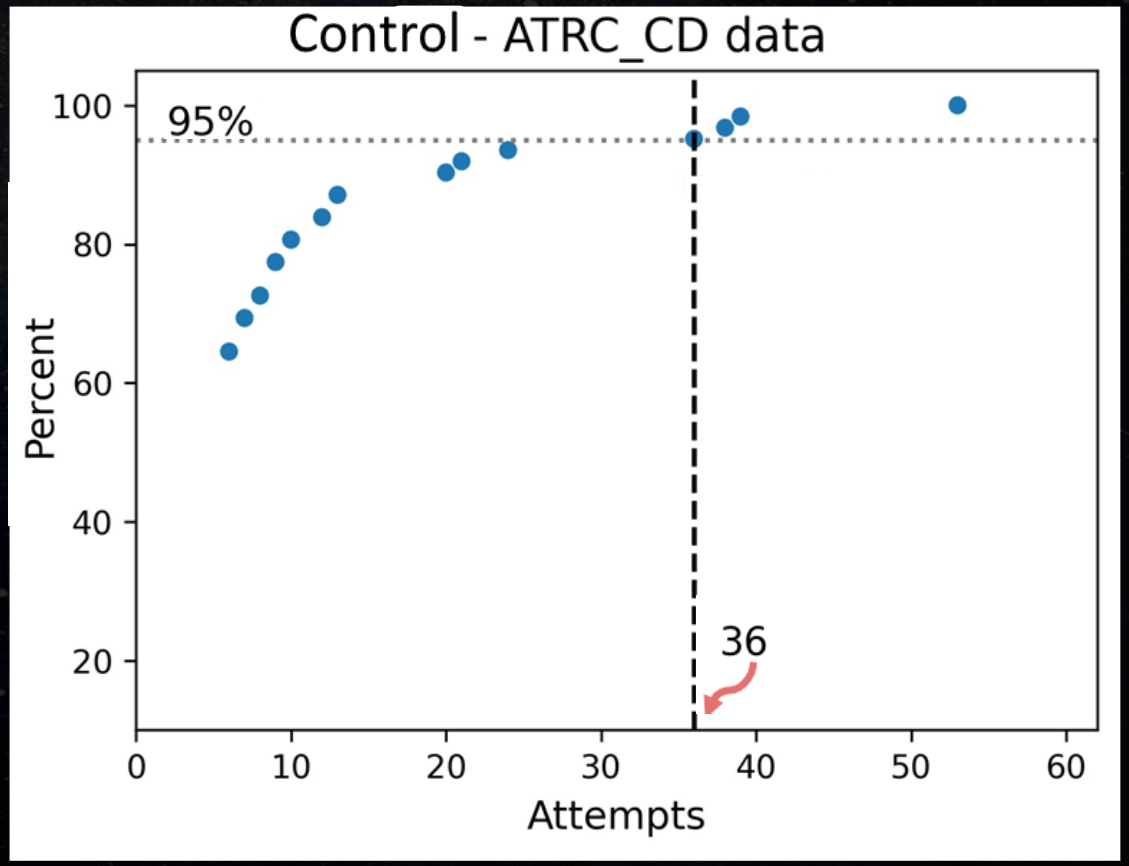
Formulation of the Supervised ML Problem

Step 1: Label rats impaired/not impaired



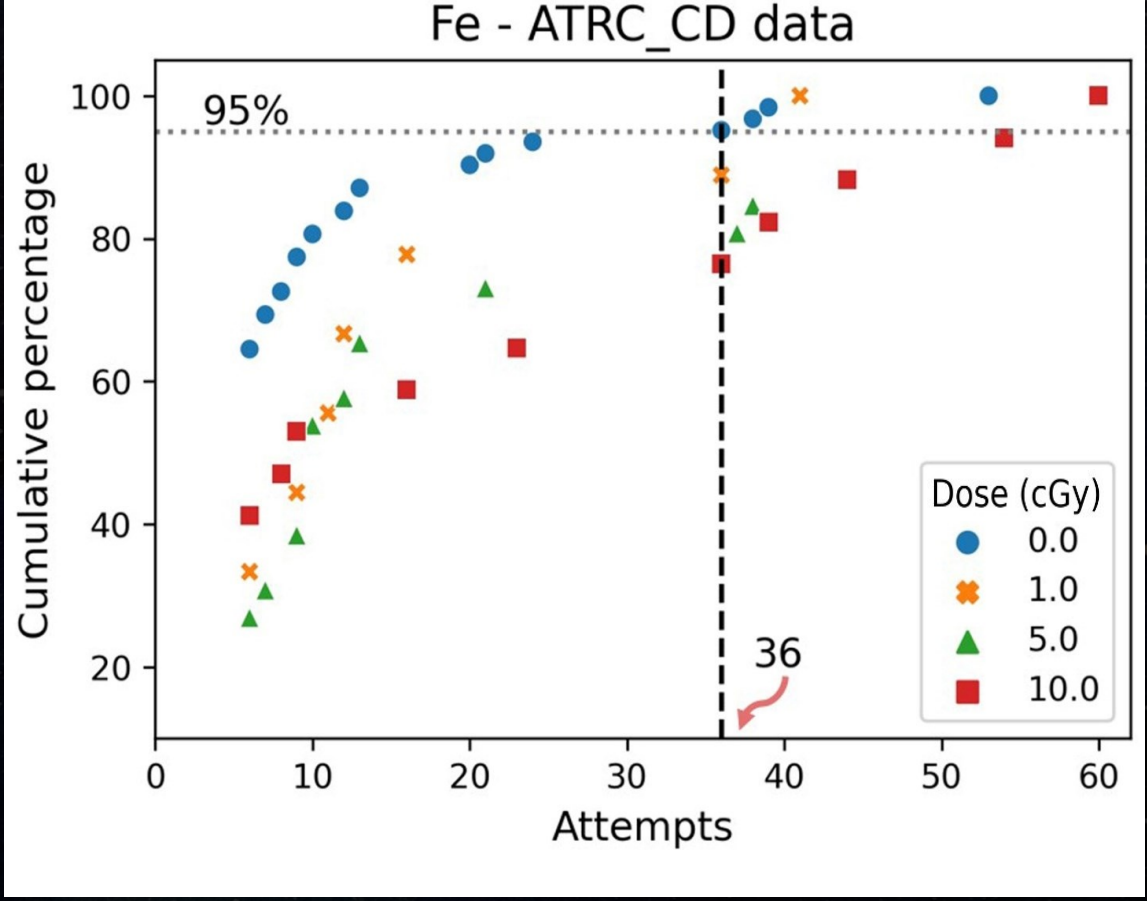
95% Threshold in CD

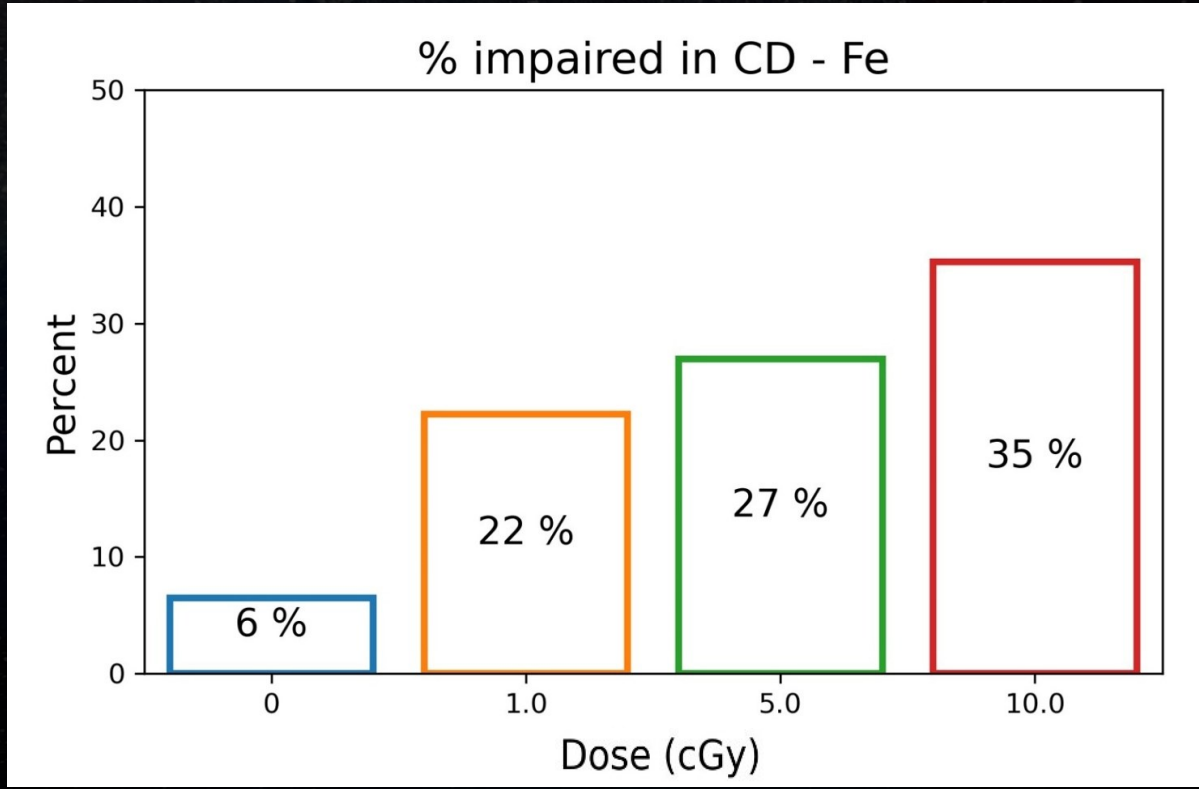
- Plot cumulative percentage for the control group
- Cumulative percentage at x = $100 \frac{\#\ rats\ with\ score \leq x}{total\ \#\ rats}$
- A 95% threshold corresponds to a y-value of 95
- Corresponding x-value is the impairment threshold



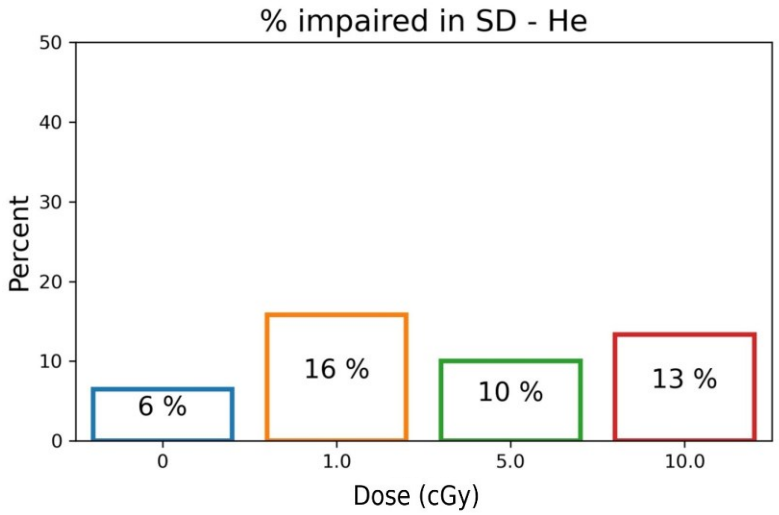
Rats' Impairment Labeling

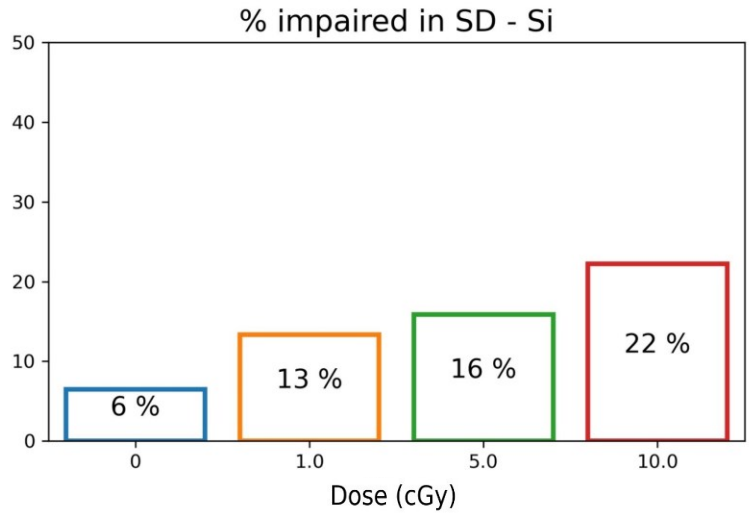
- Impaired rat: if score at or above the threshold
- Non-impaired rat: if score below the threshold

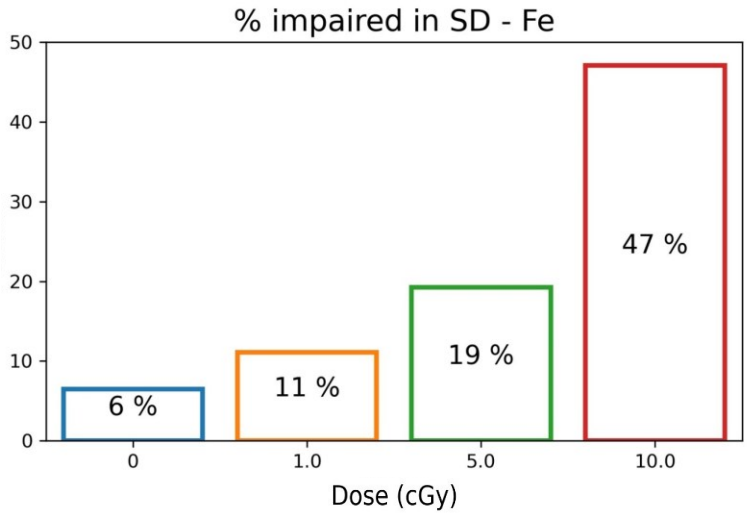


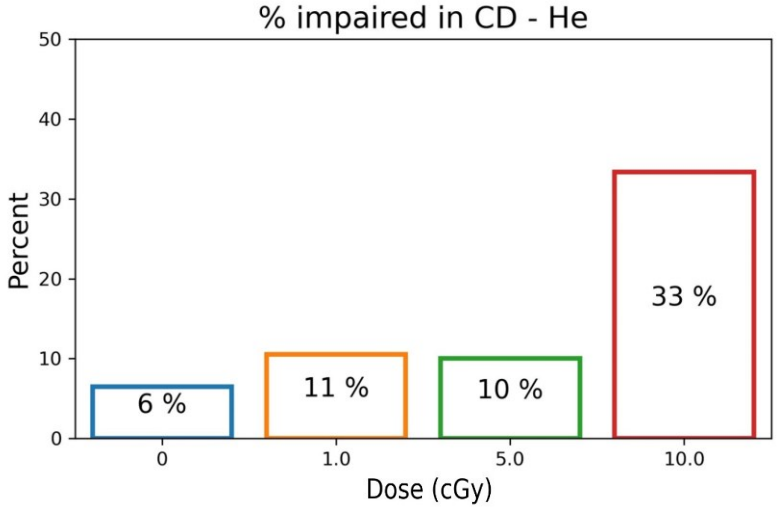


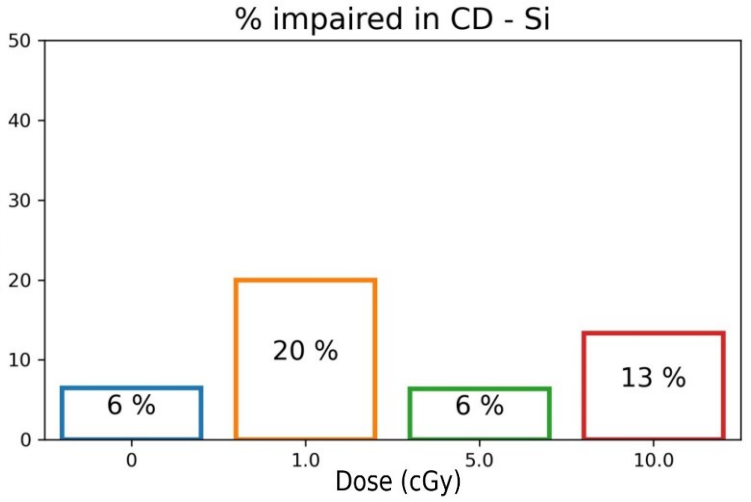
Percentage of Impaired Rats

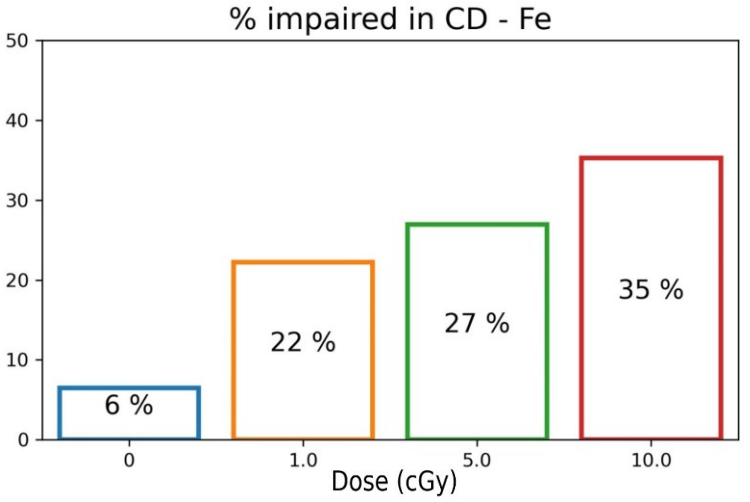








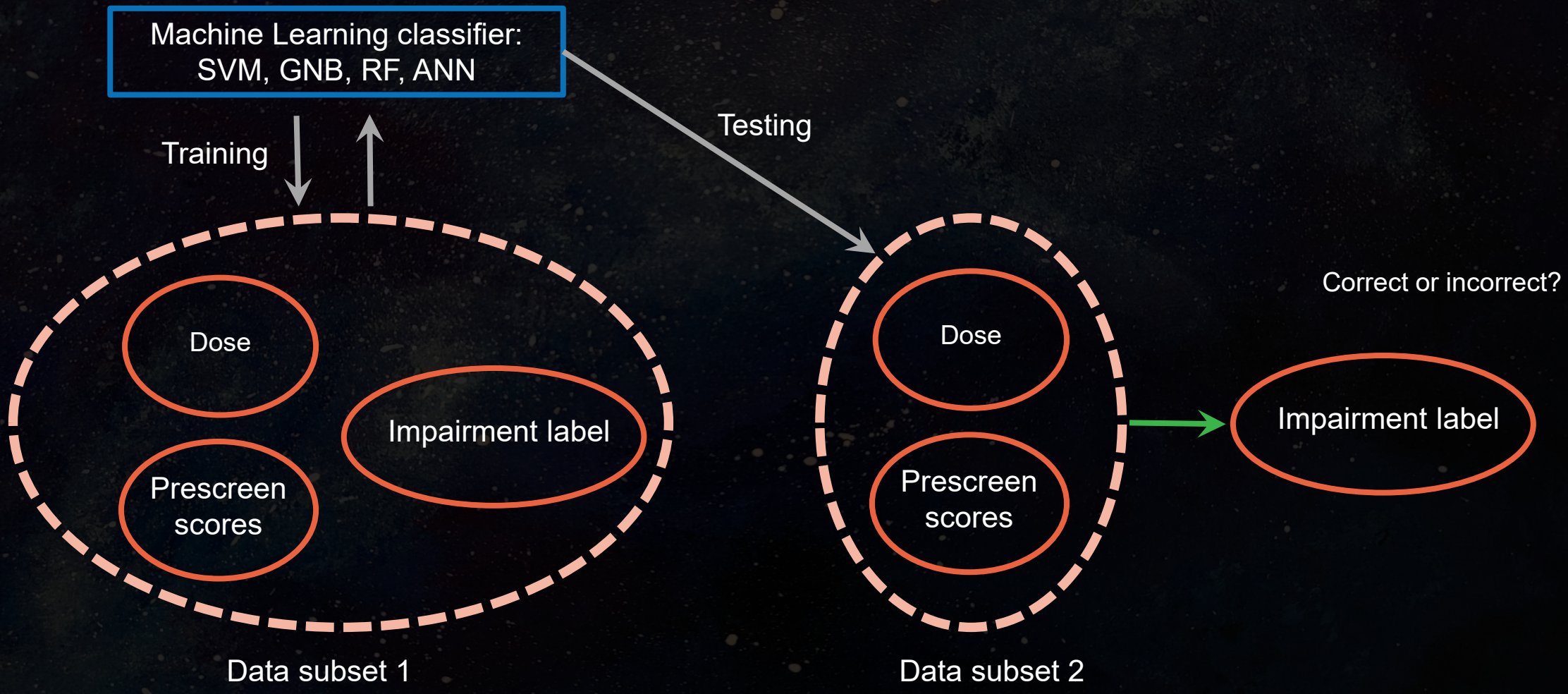




Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.

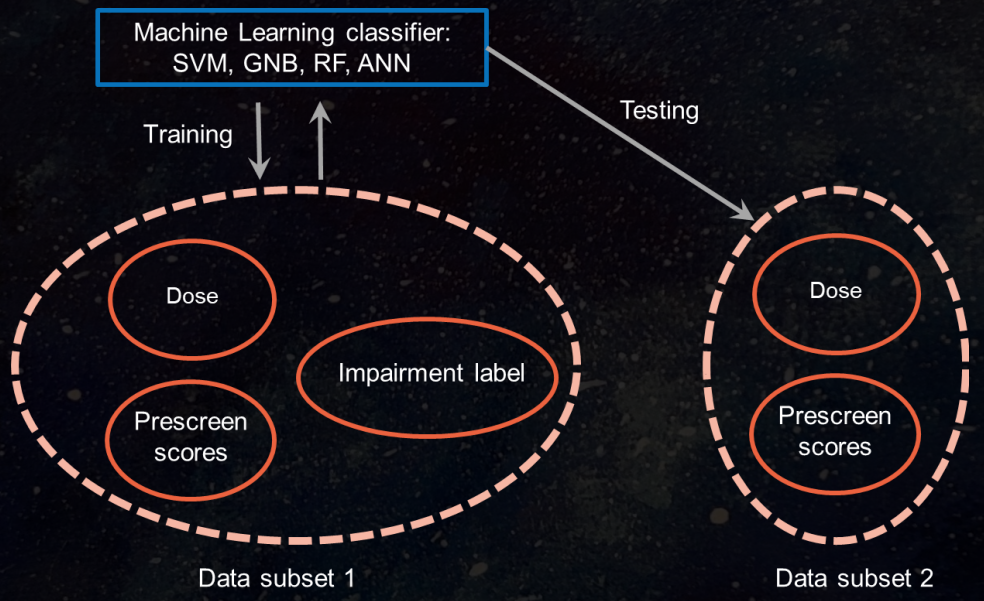
Formulation of the Supervised ML Problem

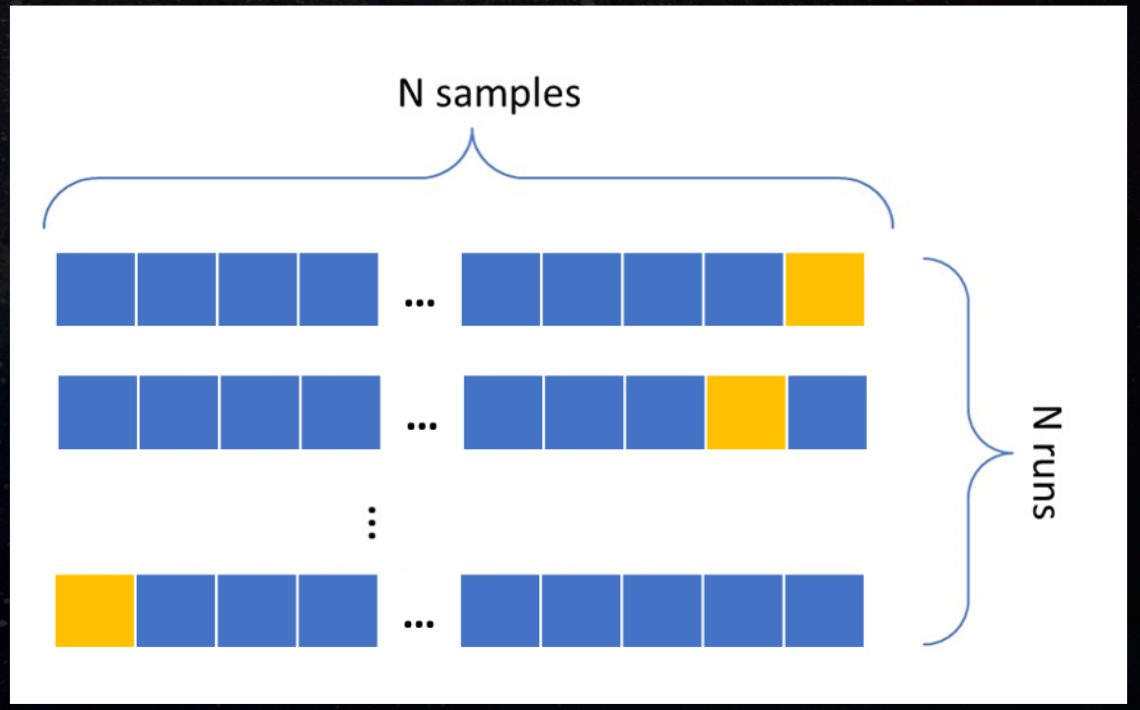
Step 2: Predict impairment at a given dose



Leave-one-out Cross Validation

Step 2: Predict impairment at a given dose

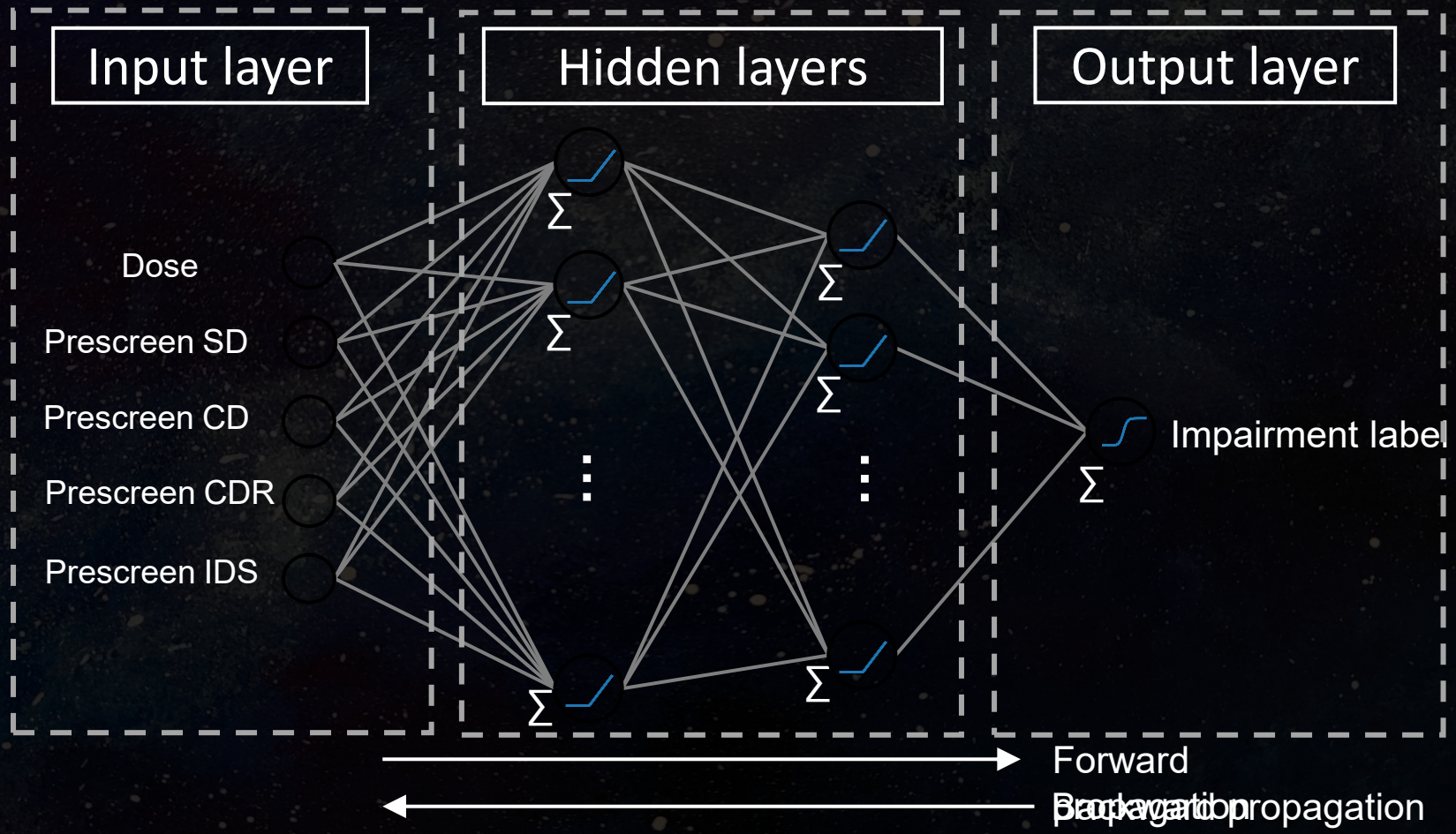




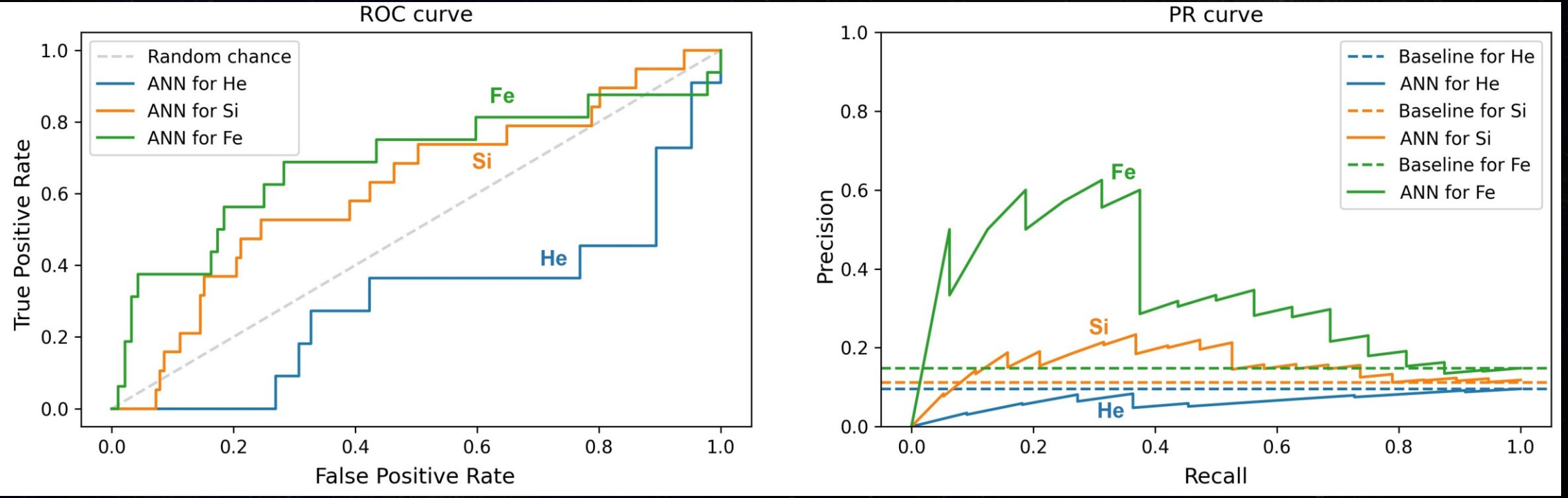
Data subset 1

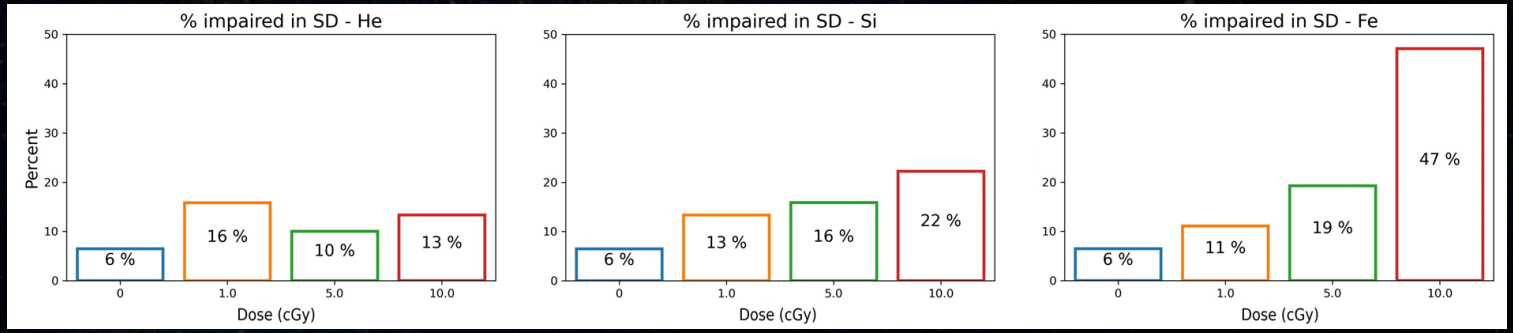
Data subset 2

Artificial Neural Network (ANN)



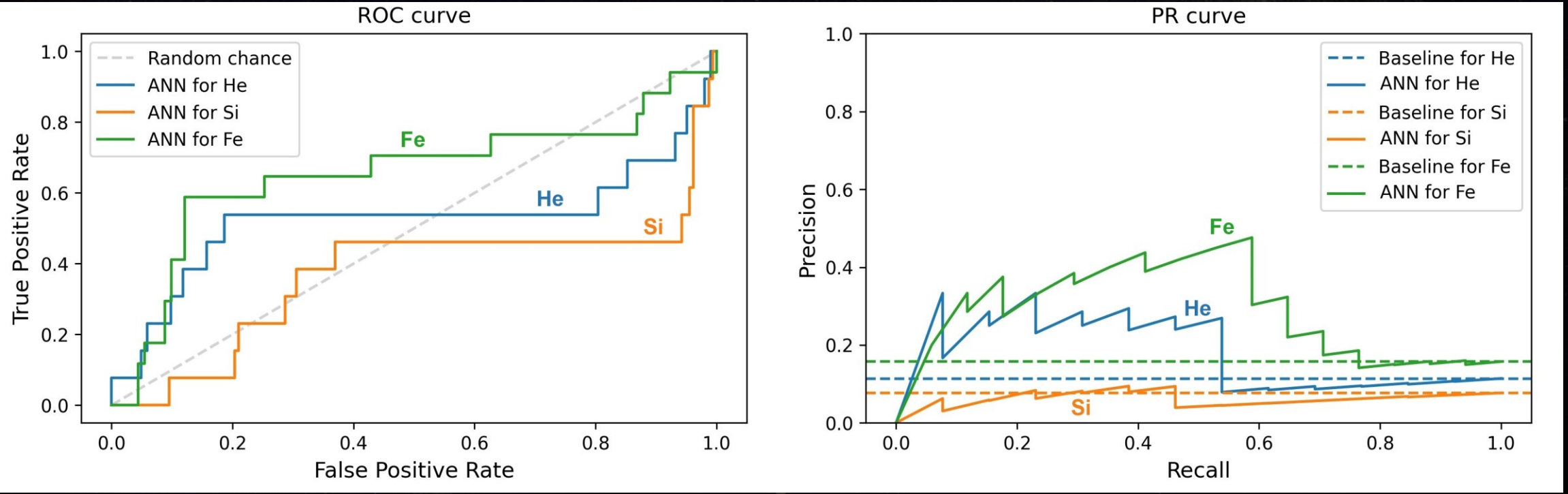
ANN Performance for SD

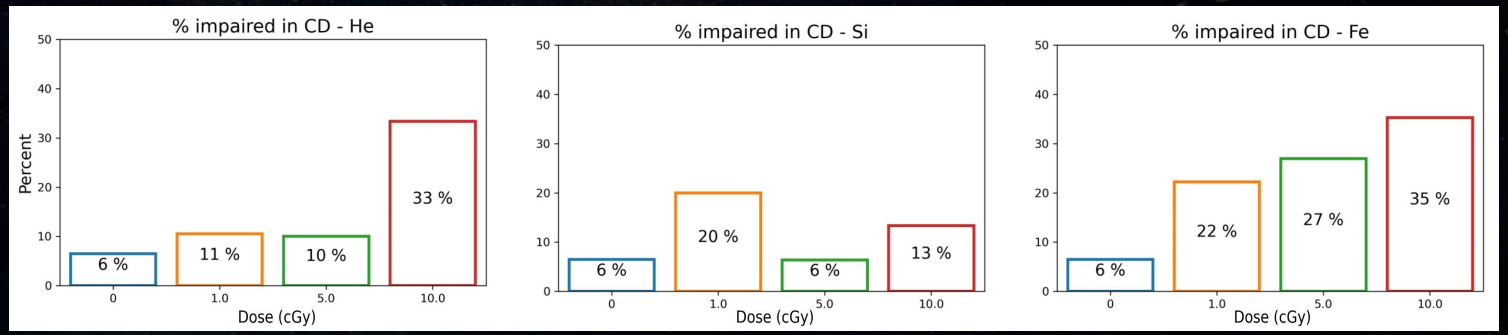




Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.

ANN Performance for CD





Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.

Conclusions

- Traditional population-based analyses show the presence of cognitive deficits as a trend at a group level
- Percent impaired values suggest deleterious dose-effect of ^{56}Fe in both SD and CD and ^{28}Si in SD
- Impairment due to ^{4}He in CD at 10 cGy
- Machine Learning models such as ANNs can pinpoint to the individuals at a higher risk of impairment
- Predictions are based on expected dose and pre-exposure scores

Limitations and Outlook

- More behavioral tests and biomarkers should be investigated on the same subjects
- With the availability of multi-ion and/or multi-stressor data, ANNs can be trained to attempt to predict the combined effect from single ions and single stressors
- Inter- and intra-variabilities in behavioral tests always present
- More work needed for the translatability of results to human subjects

For More Information

Matar, Mona, Suleyman A. Gokoglu, Matthew T. Prelich, Christopher A. Gallo, Asad K. Iqbal, Richard A. Britten, R. K. Prabhu, and Jerry G. Myers Jr. "Machine learning models to predict cognitive impairment of rodents subjected to space radiation." *Frontiers in systems neuroscience* 15 (2021).

Some Publications

- The effect of the Katz parameter on node ranking, with a medical application
  H Rehm, M Matar, P Rombach, L McIntyre, Social Network Analysis and Mining 13 (1), 132
- Biological research and self-driving labs in deep space supported by artificial intelligence
  LM Sanders, RT Scott, et al., Nature Machine Intelligence 5 (3), 208-219
- Machine Learning Models to Predict Cognitive Impairment of Rodents Subject to Space Radiation Exposure
  M Matar, SA Gokoglu, et al., Frontiers in Systems Neuroscience 15, 102
- Predicting space radiation single ion exposure in rodents: A machine learning approach
  MT Prelich, M Matar, et al., Frontiers in Systems Neuroscience 15, 715433
- Exposure to low (≤10 cGy) doses of ^{4}He particles leads to increased social withdrawal and loss of executive function performance
  JA Burket, M Matar, et al., Radiation Research 196 (4), 345-354

Internships and Jobs

My Internships Experience

Spring 2018
Data Science intern
NASA Glenn Research Center
Graphics and Visualization Lab

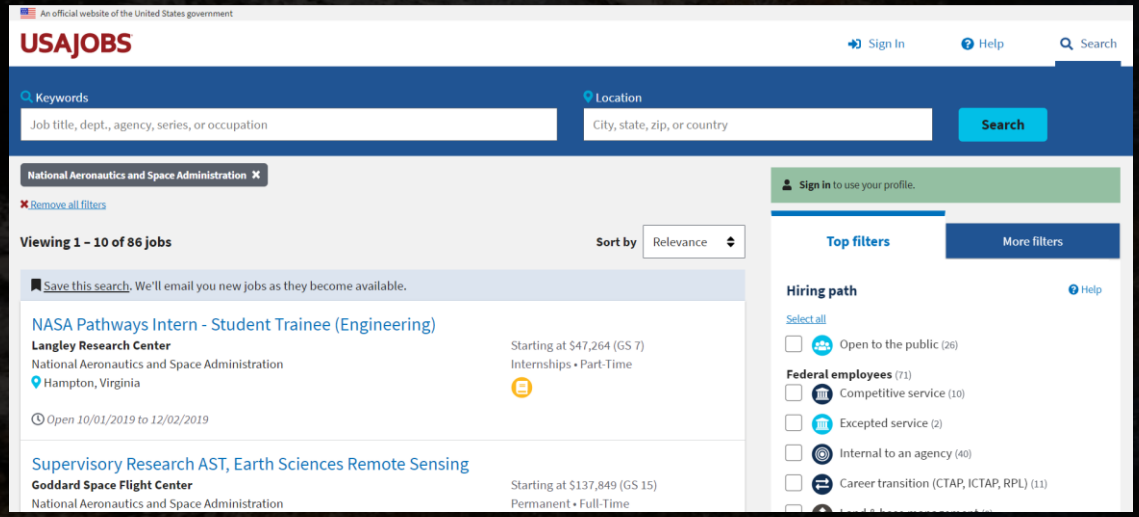
Summer 2018
Data Science intern
The J.M. Smucker Company
Coffee roasting with R&D team

Fall 2018
Pathways Trainee
NASA Glenn Research Center
Modeling team for the Human Research Program

Apply for NASA Positions

Internship
intern.nasa.gov

Direct Hire
usajobs.gov




Thank You ☺
Questions?