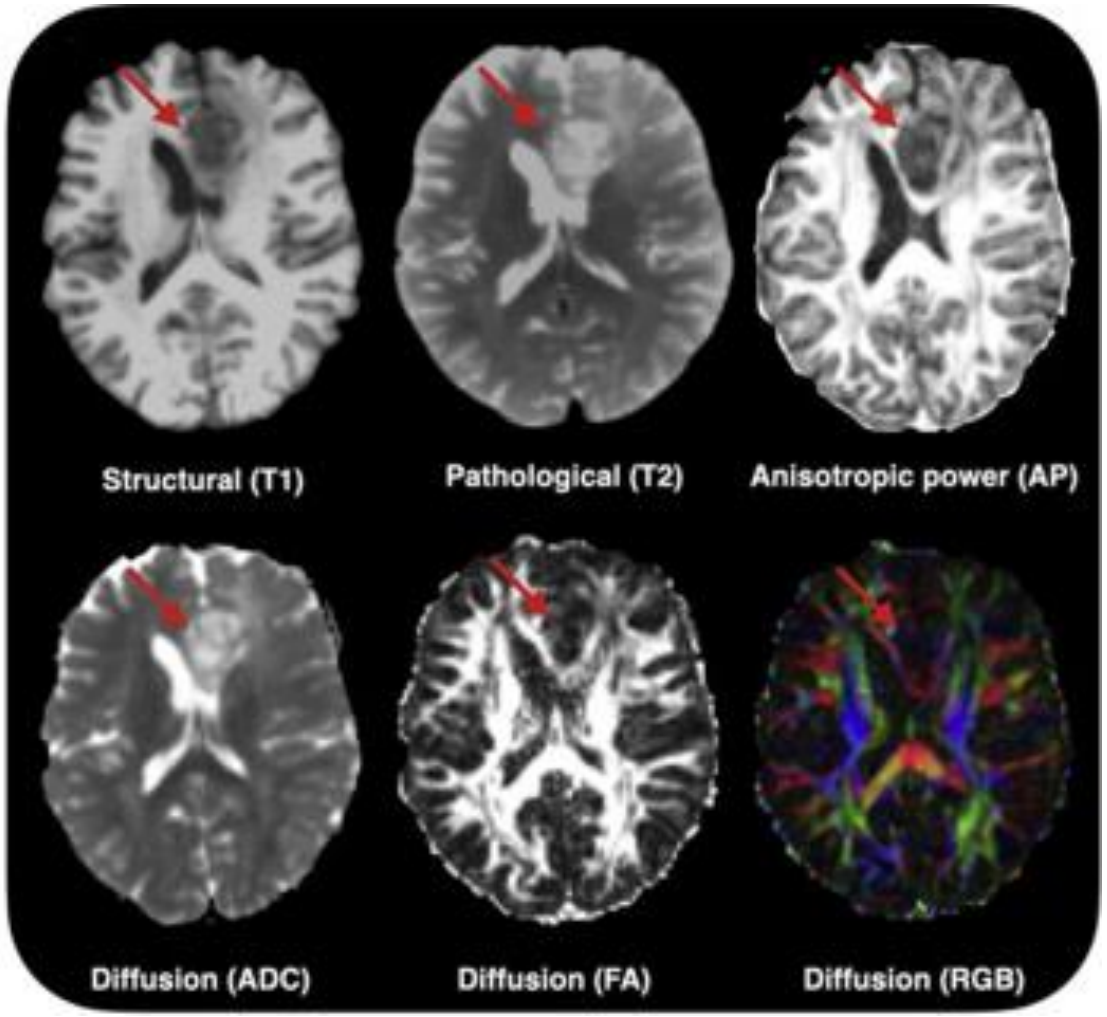
Medical/Bio Research Topics Ⅰ: Week 01 (03.03.2023)

Introduction to the brain imaging-based artificial intelligence models

(뇌영상 기반 인공지능 모델 소개)

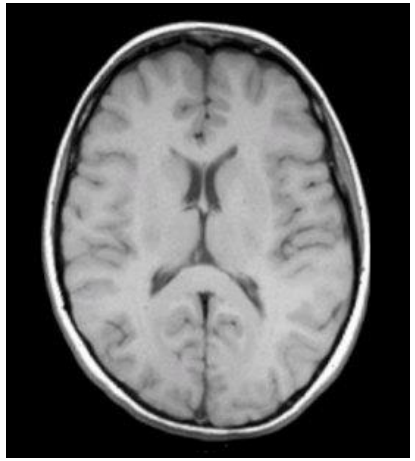
Practice of Radiology

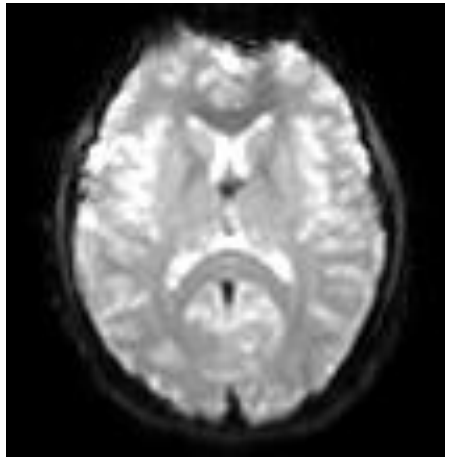
- Disease detection
- Disease management
- Patient outcome prediction

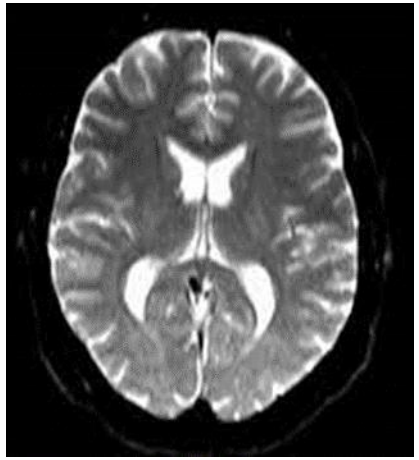


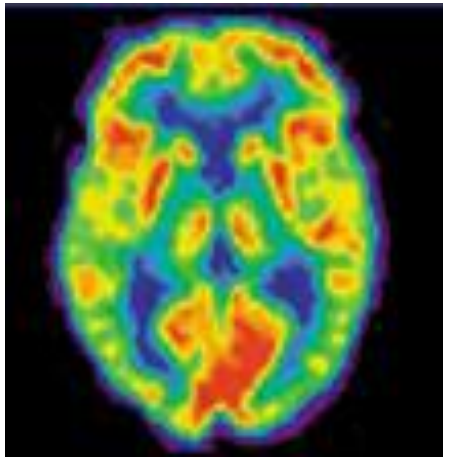
Brain lesion detection

Brain Imaging









CT | **Structural MRI** | **Functional MRI** | **Diffusion-weighted MRI** | **PET**

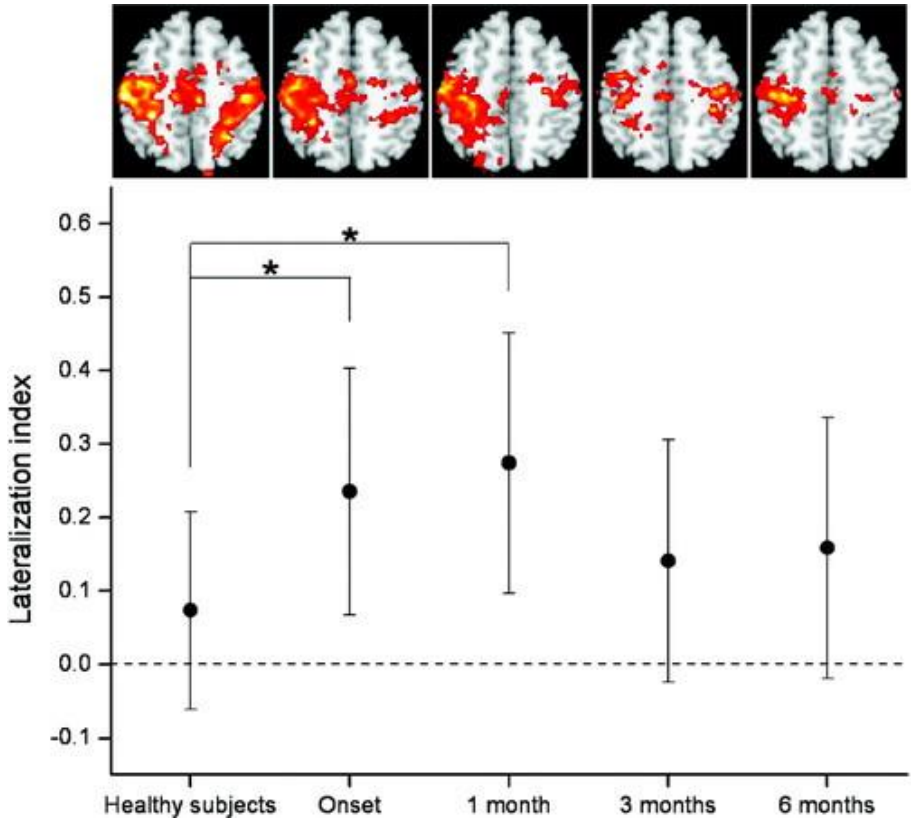
CT, Computed Tomography (컴퓨터단층촬영)
MRI, Magnetic Resonance Imaging (자기공명영상)
PET, Positron Emission Tomography (양전자방출단층촬영)

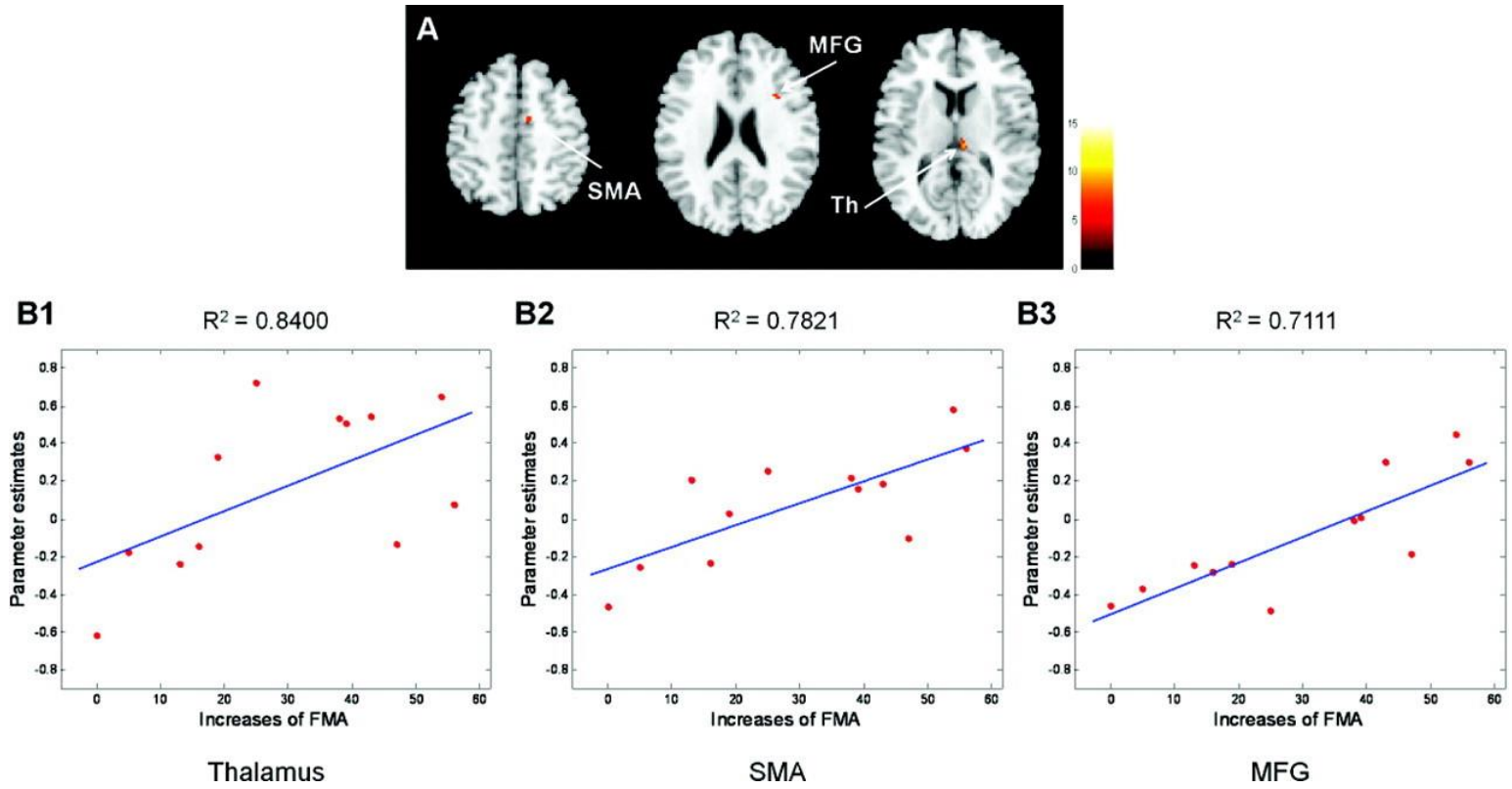
MRI

- "*A workhorse technology because of the diversity of information attainable using the same scanner to acquire images*" (D.C. Van Essen)
- Three main types of MRI
  - Structural MRI
  - Functional MRI
  - Diffusion-weighted MRI

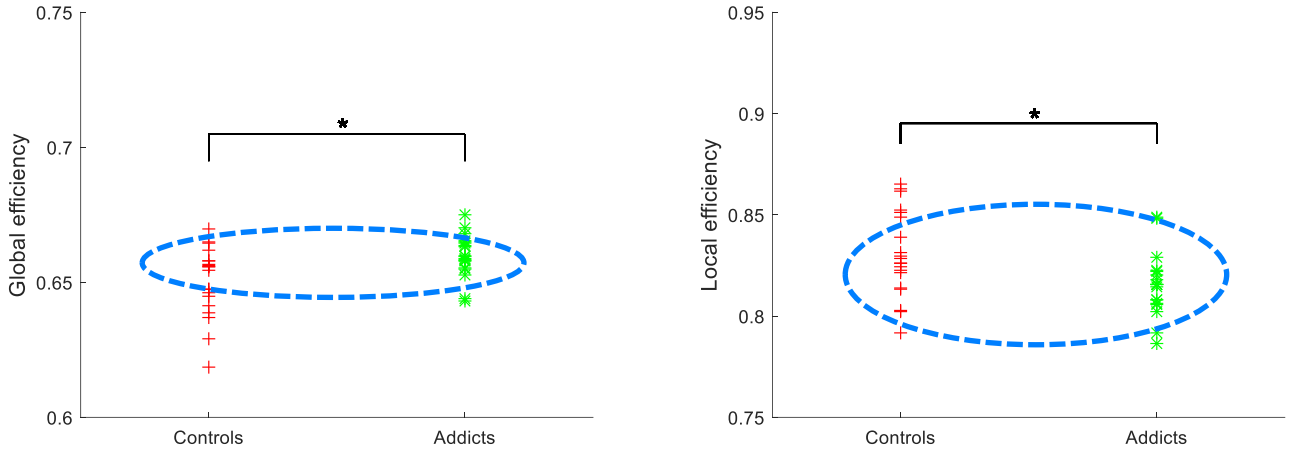
Clinical MRI Studies

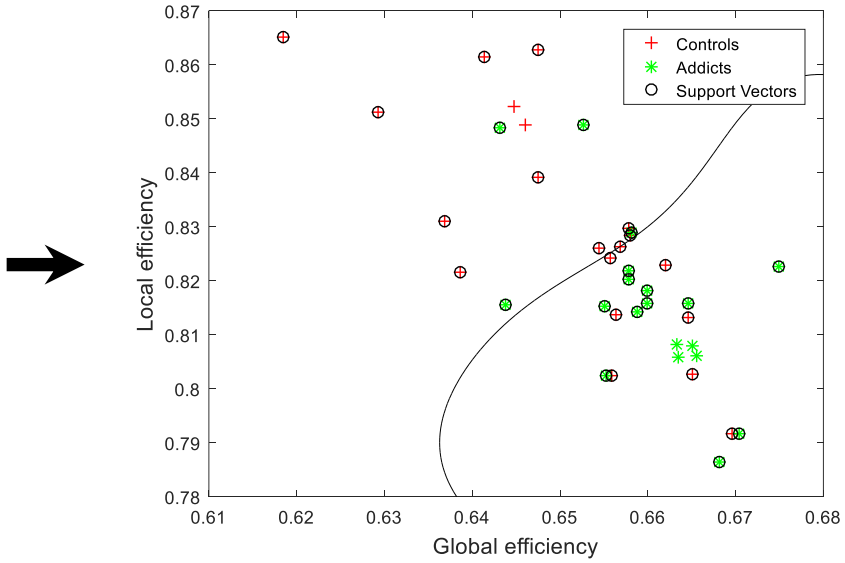
- Brain changes in recovery after stroke [Park et al, 2011]



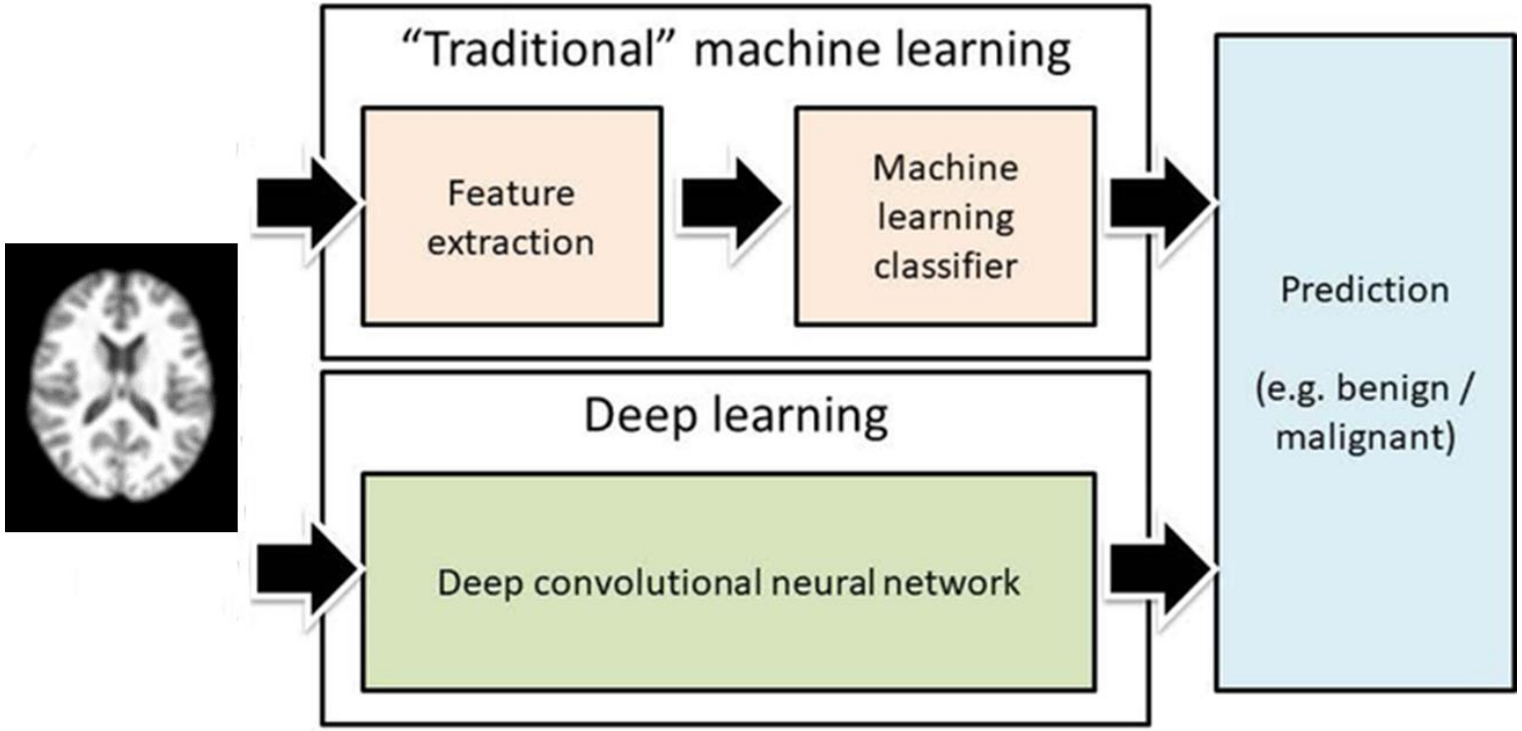

A
MFG
SMA
Th
15
10
5
0
B1
R² = 0.8400
B2
R² = 0.7821
B3
R² = 0.7111
Parameter estimates
Increases of FMA
Thalamus
SMA
MFG

- Classification beyond describing group differences



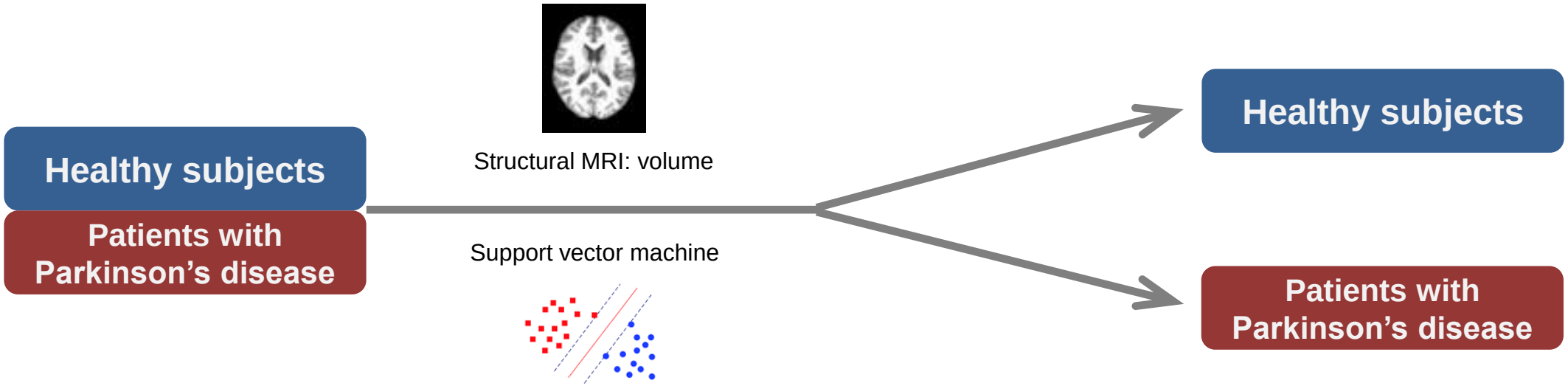


MRI Machine Learning Studies

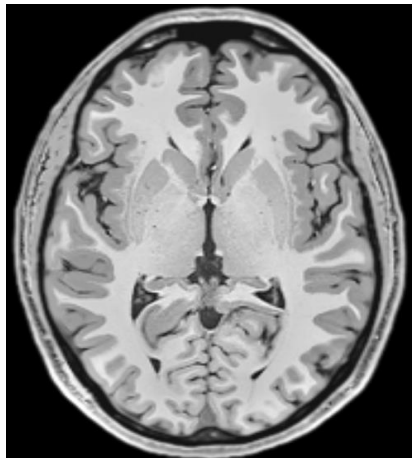


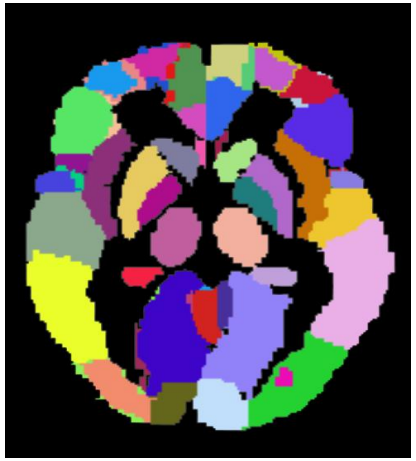
Difference between traditional machine learning and deep learning [Mazurowski et al., 2018]

- Classification

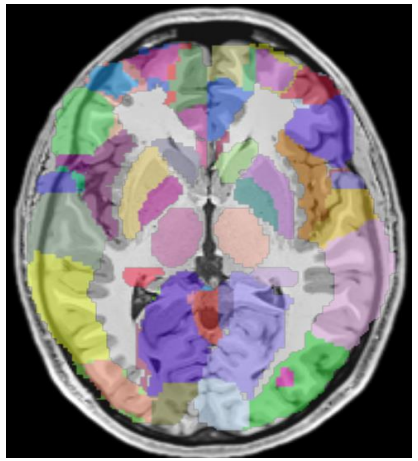


[Park et al., 2020]





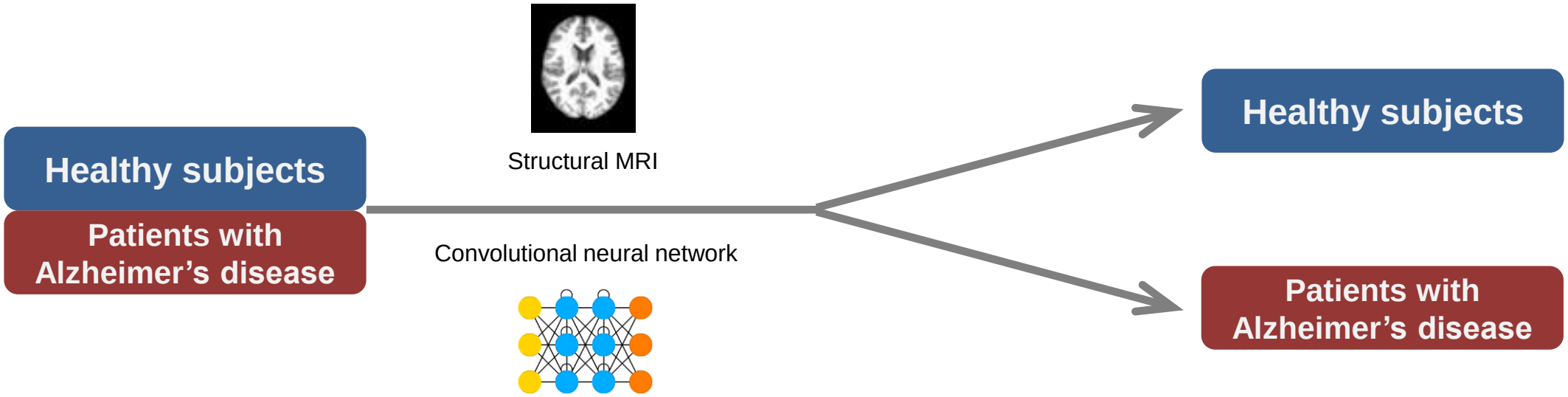
Brain atlas



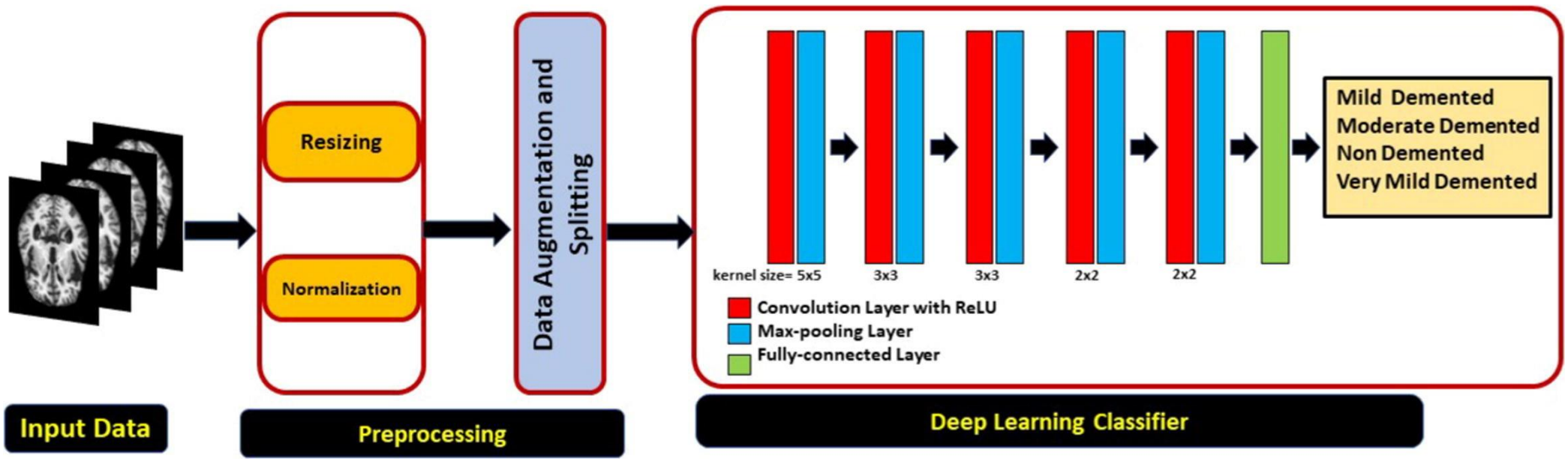
Features

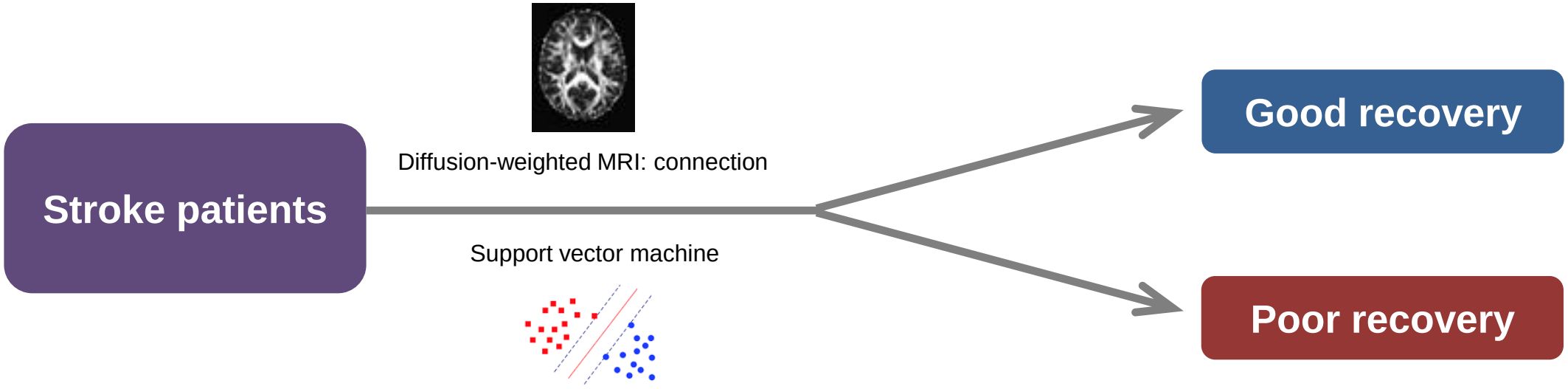
Samples

	Brain area 1 volume	Brain area 2 volume	Brain area 3 volume	…
Subject 1	-	-	-	-
Subject 2	-	-	-	-
Subject 3	-	-	-	-
⋮	-	-	-	-

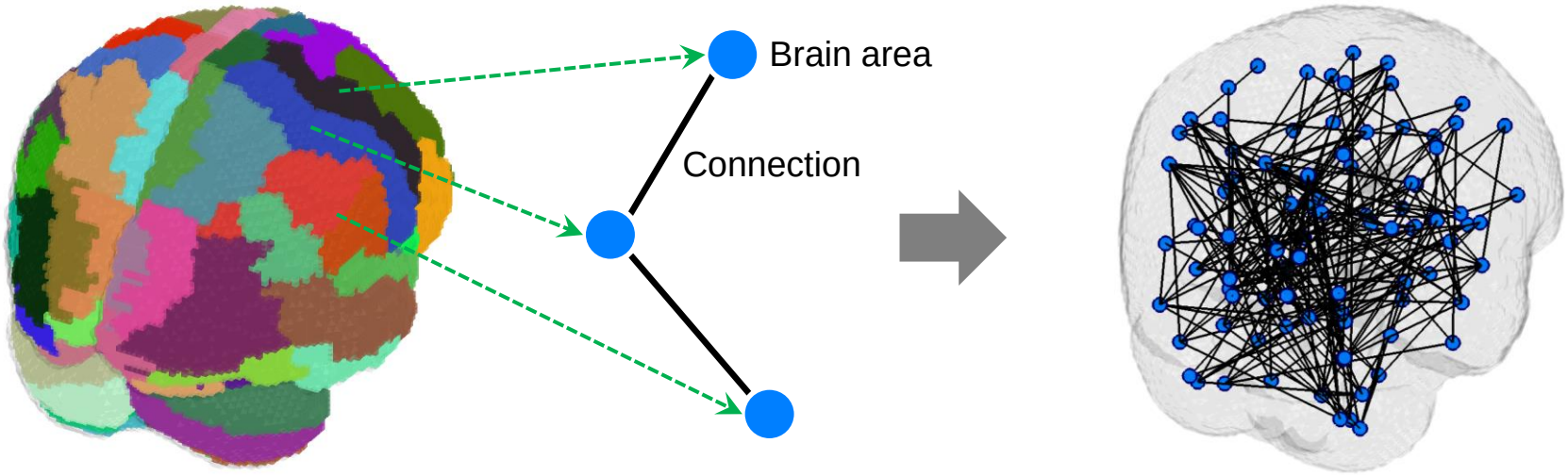


[EL-Geneedy et al., 2023]


Resizing
Normalization
Data Augmentation and Splitting
kernel size= 5x5
3x3
3x3
2x2
2x2
Convolution Layer with ReLU
Max-pooling Layer
Fully-connected Layer
Mild Demented
Moderate Demented
Non Demented
Very Mild Demented
Input Data
Preprocessing
Deep Learning Classifier



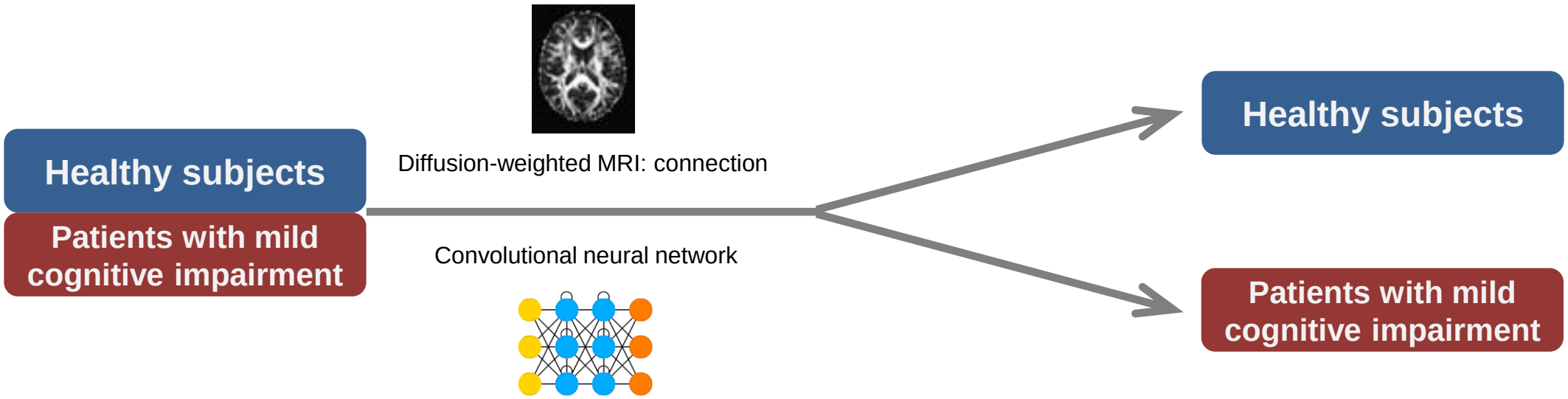
[Koch et al., 2021]



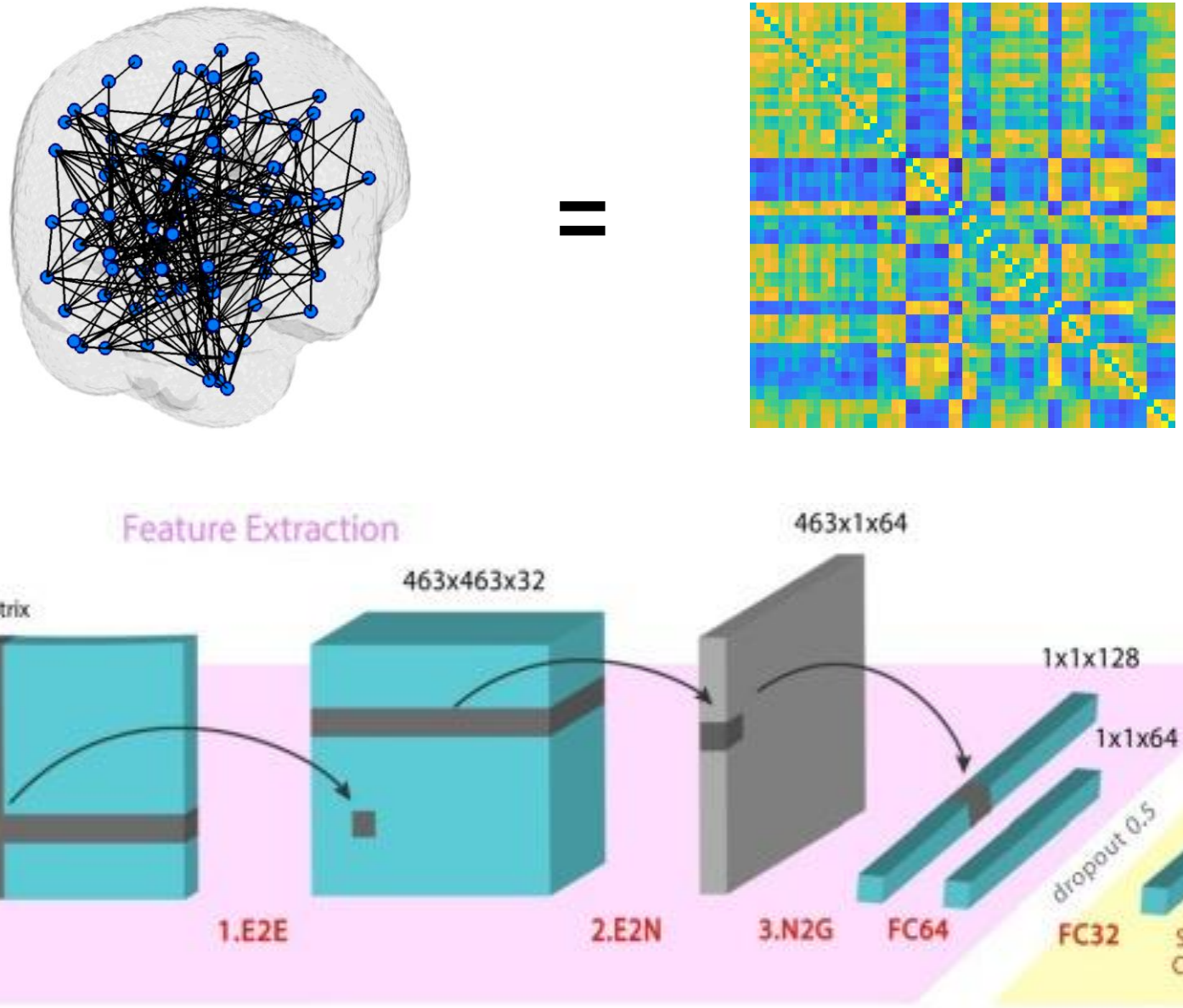
Features

Samples

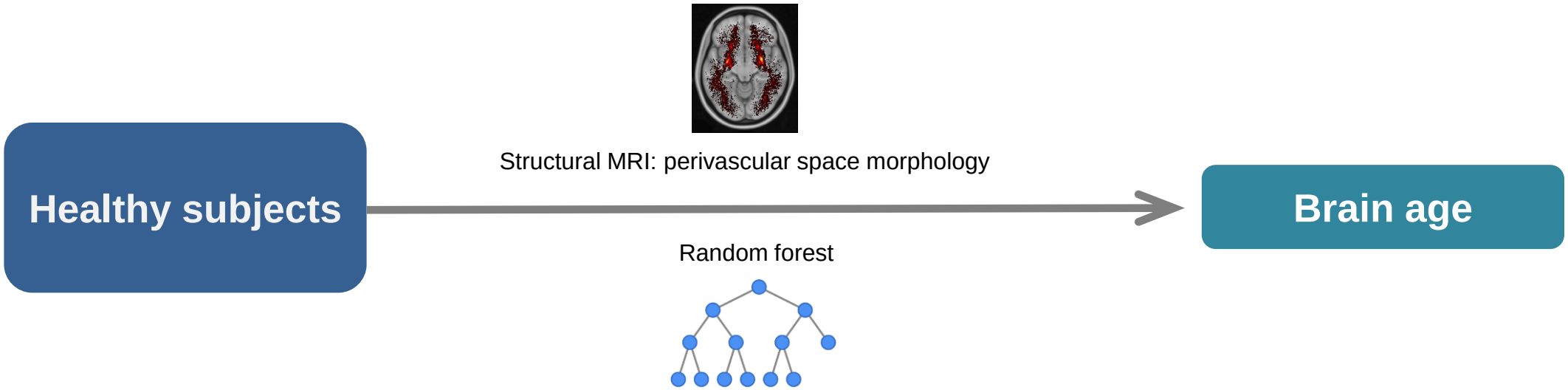
	Brain areas 1 – 2 connection	Brain areas 1 – 3 connection	Brain areas 1 – 4 connection	…
Subject 1	-	-	-	-
Subject 2	-	-	-	-
Subject 3	-	-	-	-
⋮	-	-	-	-



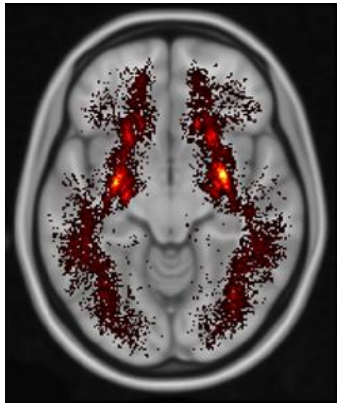
[Kolahkaj et al., 2023]


=
Feature Extraction
463x463x1
Input Connectivity Matrix
463x463x32
463x1x64
1x1x128
1x1x64
1x1x32
Classification
(NC/EMCI/MCI)
dropout 0.5
NC
EMCI
MCI
feature maps
1.E2E
2.E2N
3.N2G
FC64
FC32
Softmax
Classifier

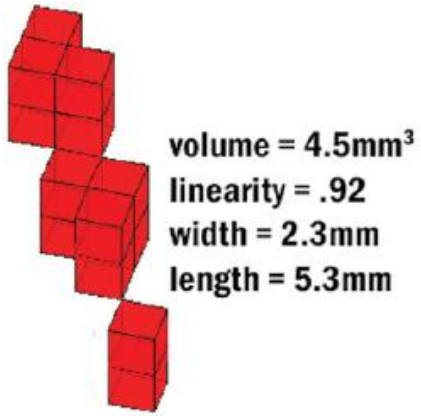
- Regression



[Park et al., 2023]



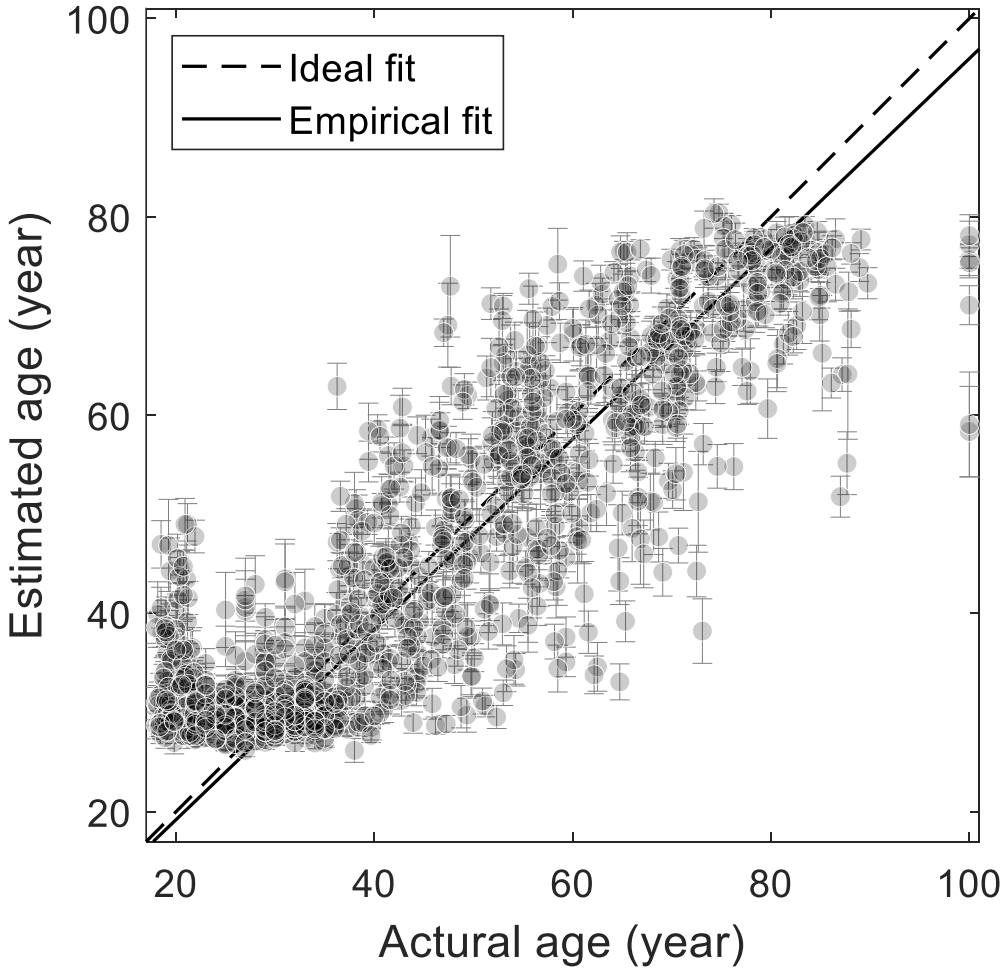
Perivascular space (PVS)



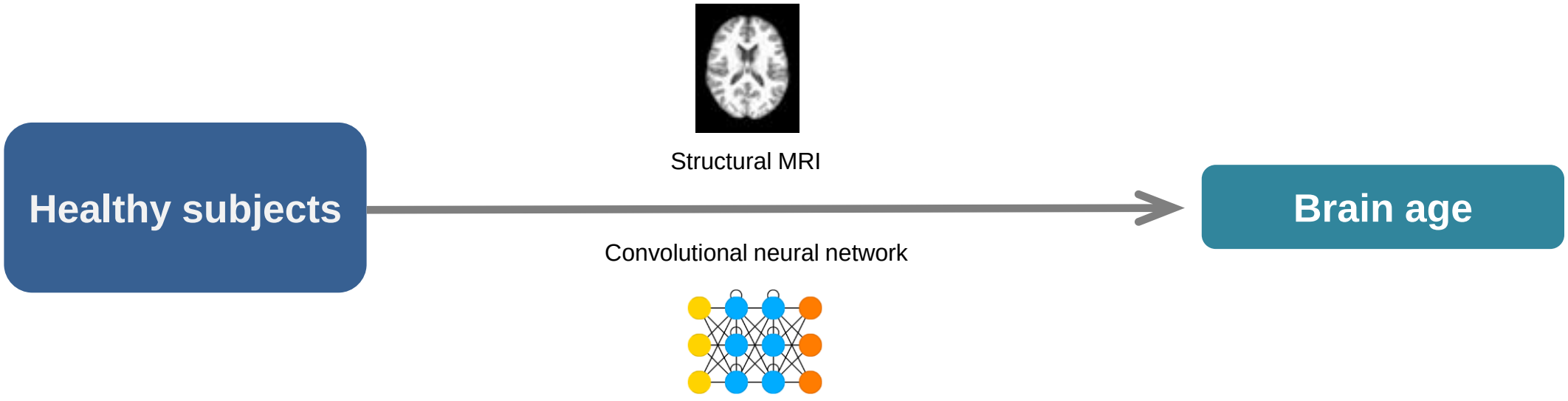
Features →

Samples ↓

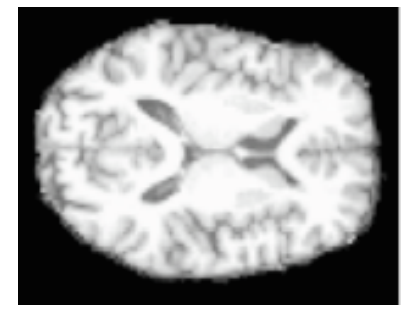
	Brain area 1 PVS volume	Brain area 1 PVS linearity	Brain areas 1 PVS width	…
Subject 1	-	-	-	-
Subject 2	-	-	-	-
Subject 3	-	-	-	-
⋮	-	-	-	-



Actual age (chronological age) vs. estimated age (brain age)



[Yin et al., 2023]



Input

Conv3D
MaxPool3D
BatchNorm

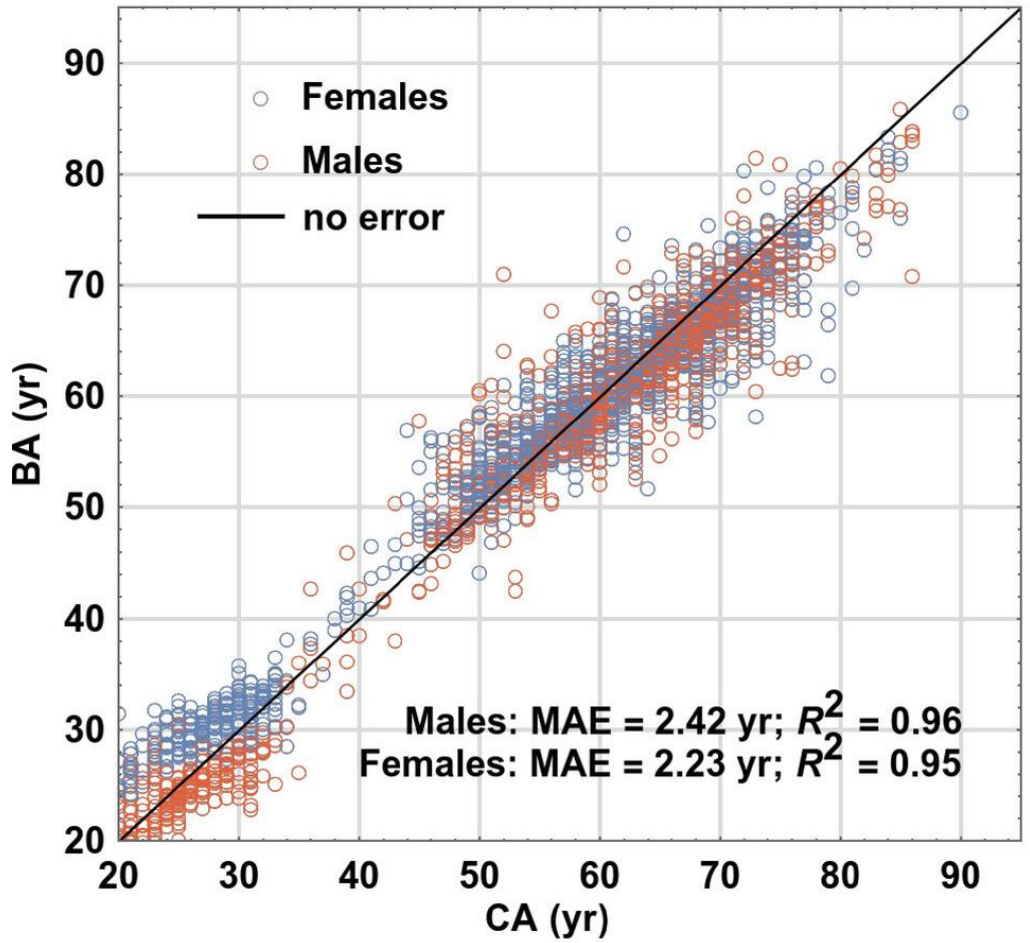
Conv3D
MaxPool3D
BatchNorm
Dropout

Conv3D
MaxPool3D
BatchNorm

GlobalAvgPool
Dense 128
Dropout

Dense 1

estimated BA



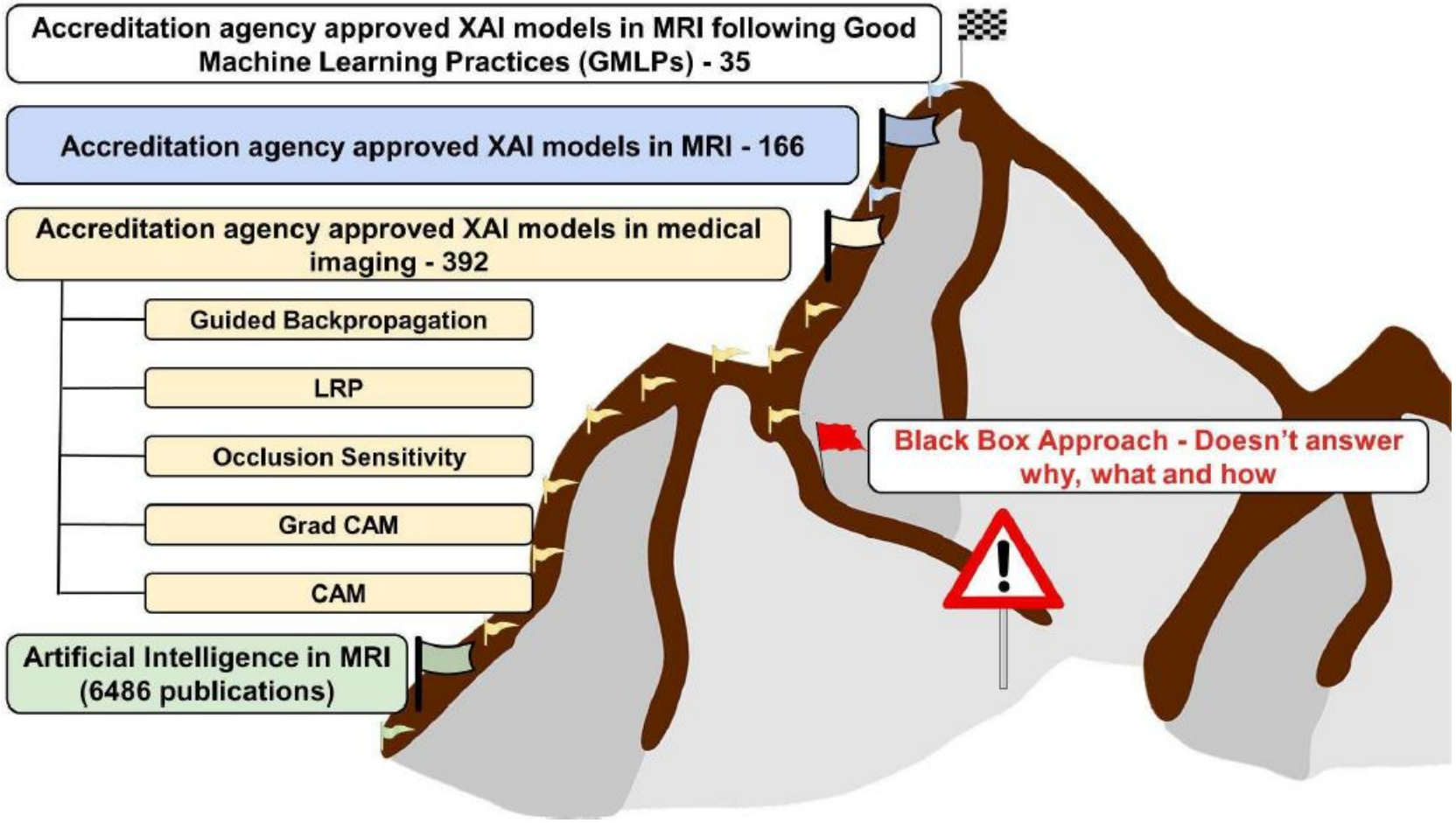
Actual age (chronological age) vs. estimated age (brain age)

Demands for MRI Machine Learning

- Good Machine Learning Practices (GMLPs)
- Explainable artificial intelligence (XAI)
  - For visualizing and interpreting machine learning predictions
  - Article 15 GDPR (General Data Protection Regulation) [https://gdpr-info.eu/art-15-gdpr]: right of access by the data subject
    - Patients have the right to request an explanation for how a given diagnosis was reached

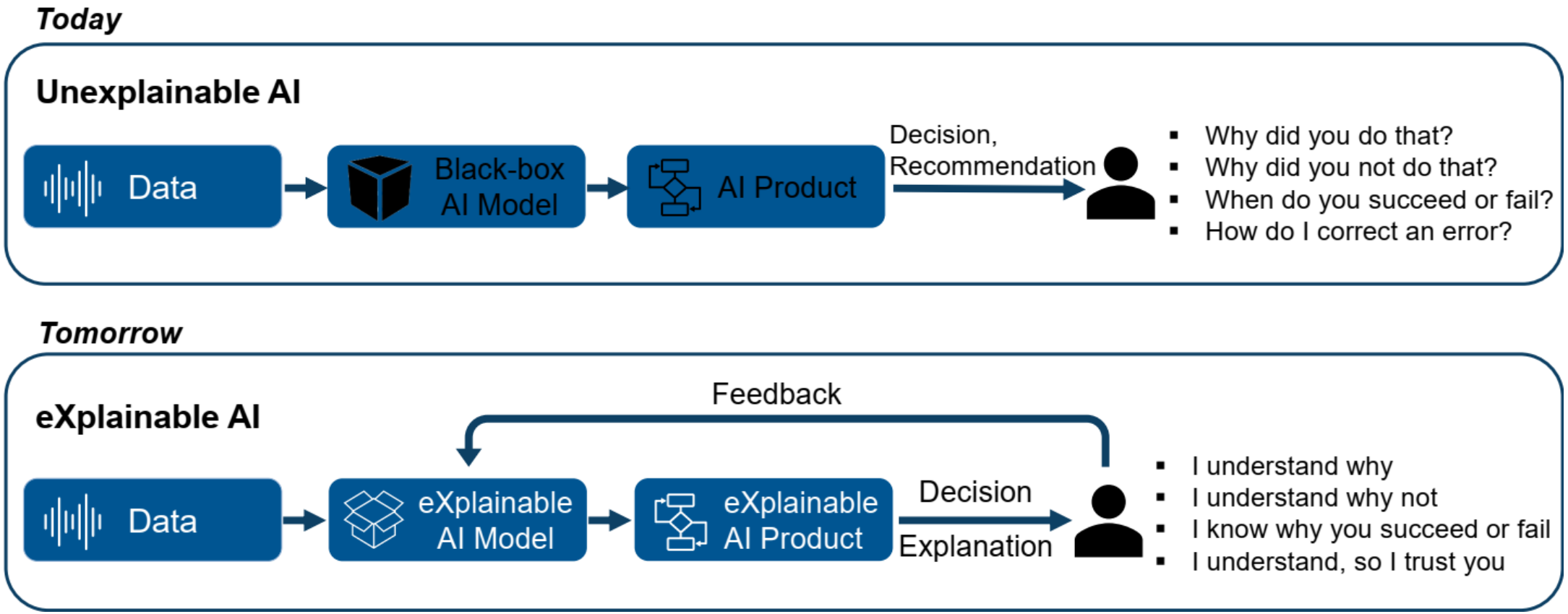
Checklist of GMLPs for brain MRI		
1.	Are neuroradiologists, neuroimaging scientists, MR technician and data scientist working together throughout the whole life cycle of the product?	
2.	Is the patient's personal information anonymous in the brain MR images?	
3.	Is the metadata being filled for each patient scan with proper details of all parameters?	
4.	Does training and testing MR datasets contain different scans? There shouldn't be any common scan in both datasets.	
5.	Does reference MR dataset for validation of model have completely unique scans with same parameters as training and testing dataset?	
6.	Are you using the model for segmenting brain structures from the specific contrast for which it has been trained for? If so, don't use it for other contrasts.	
7.	Is the output of the model accepted and readable by the neuroradiologist?	
8.	Has the model been tested in the neuroradiology department under the supervision of an expert neuroradiologist before deployment?	
9.	Are the precautions and potential dangers of using the model explicitly mentioned?	
10.	Is the model being updated frequently for incorporating the changes in the new scans that may occur naturally?	

[https://doi.org/10.48550/arXiv.2301.01241]



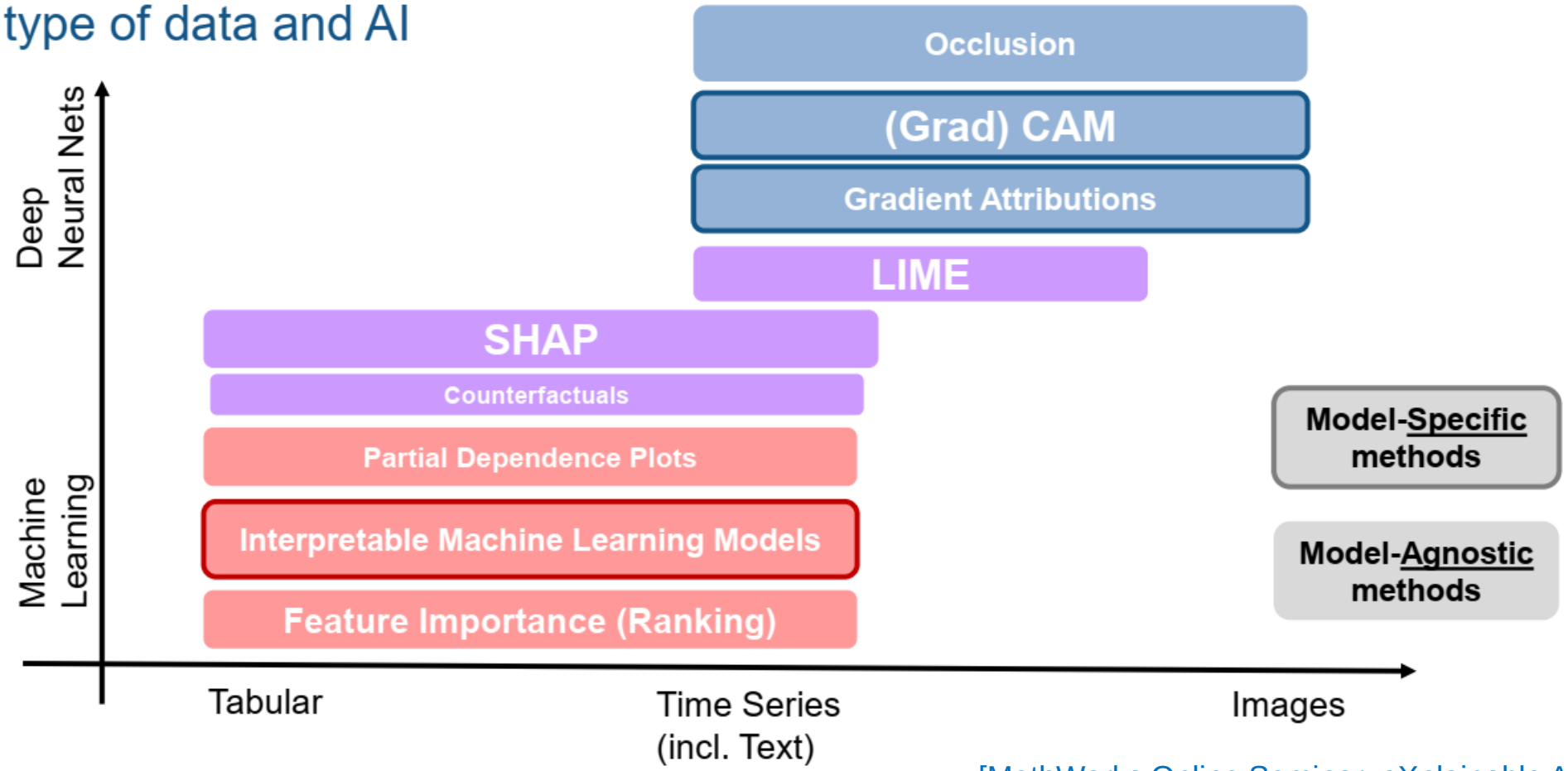
[https://doi.org/10.48550/arXiv.2301.01241]

Publications of MRI machine learning

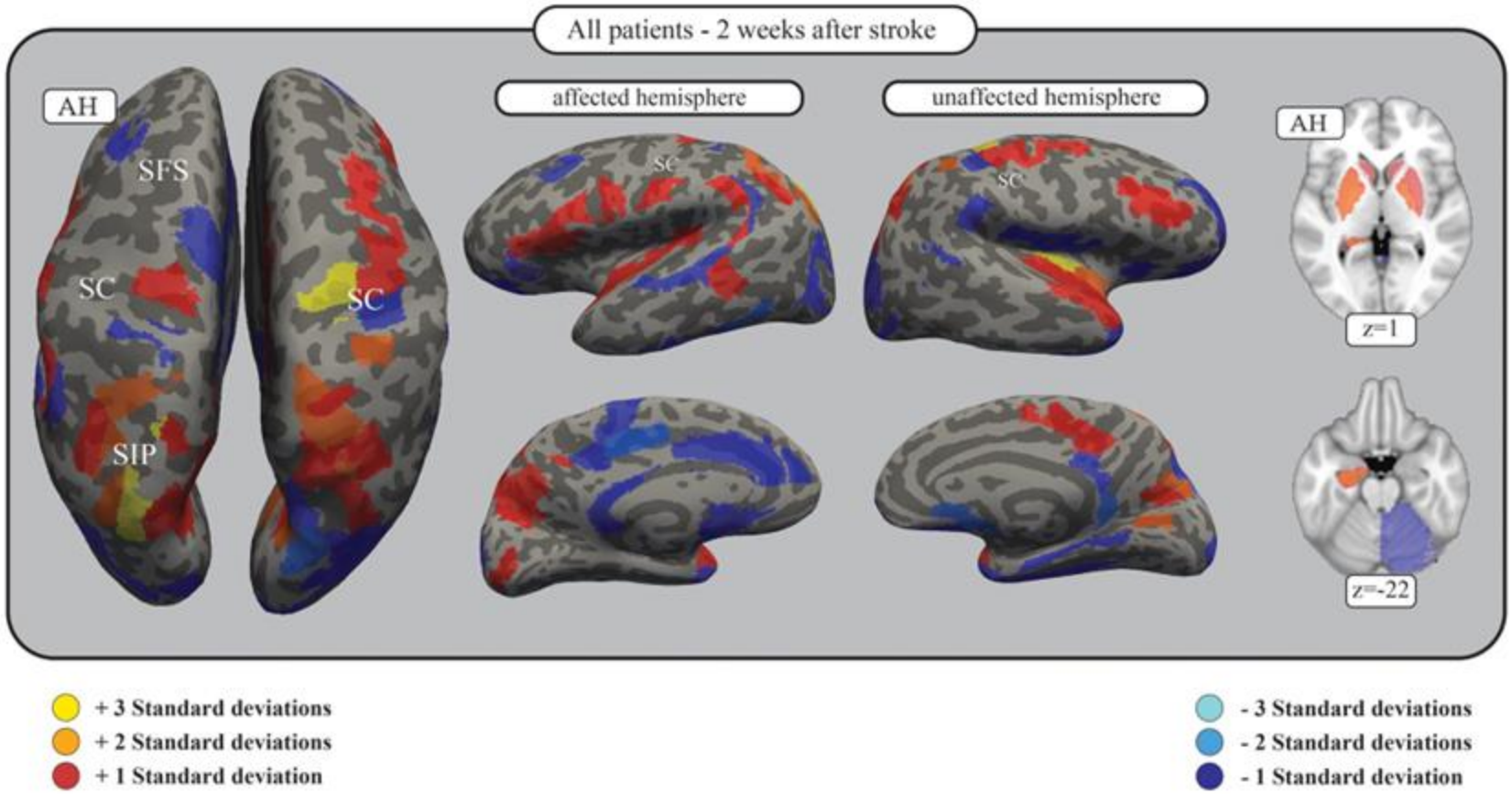


[MathWorks Online Seminar: eXplainable AI and AI V&V]

Wide range of techniques with varying applicability depending on type of data and AI

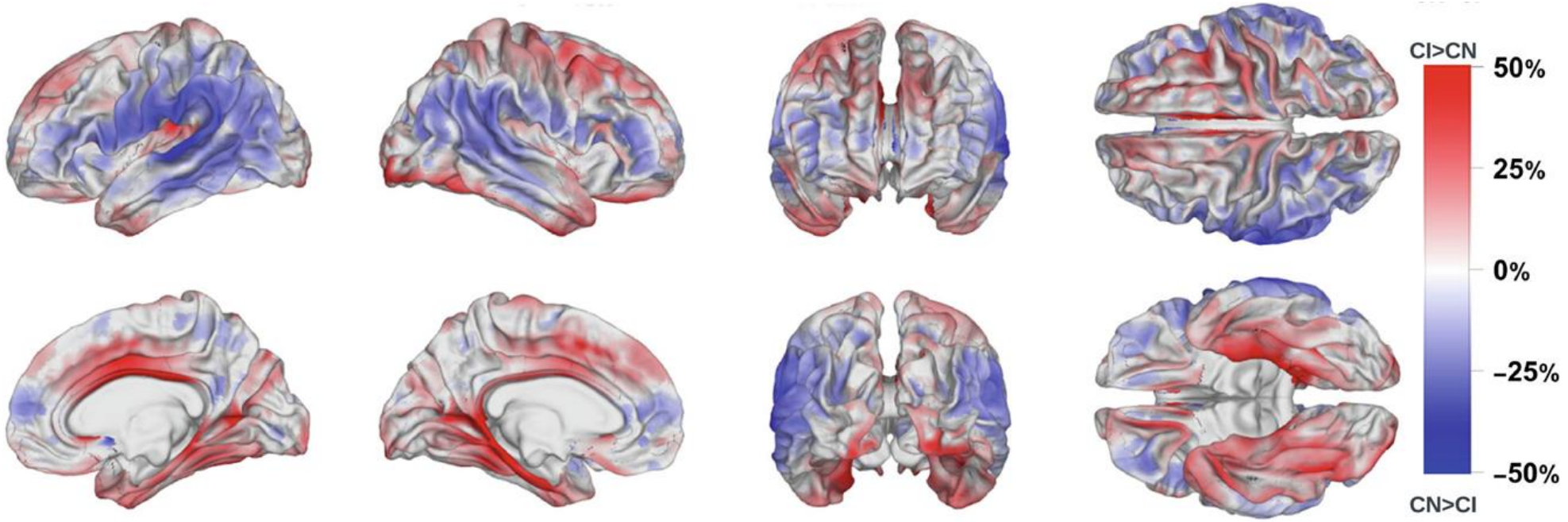


[MathWorks Online Seminar: eXplainable AI and AI V&V]



[Koch et al., 2021]

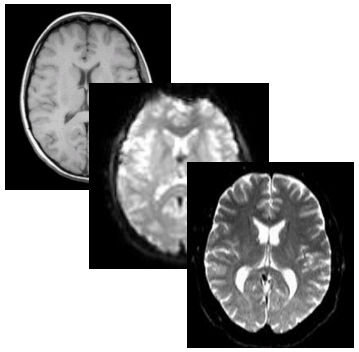
Brain areas contributing to predictions

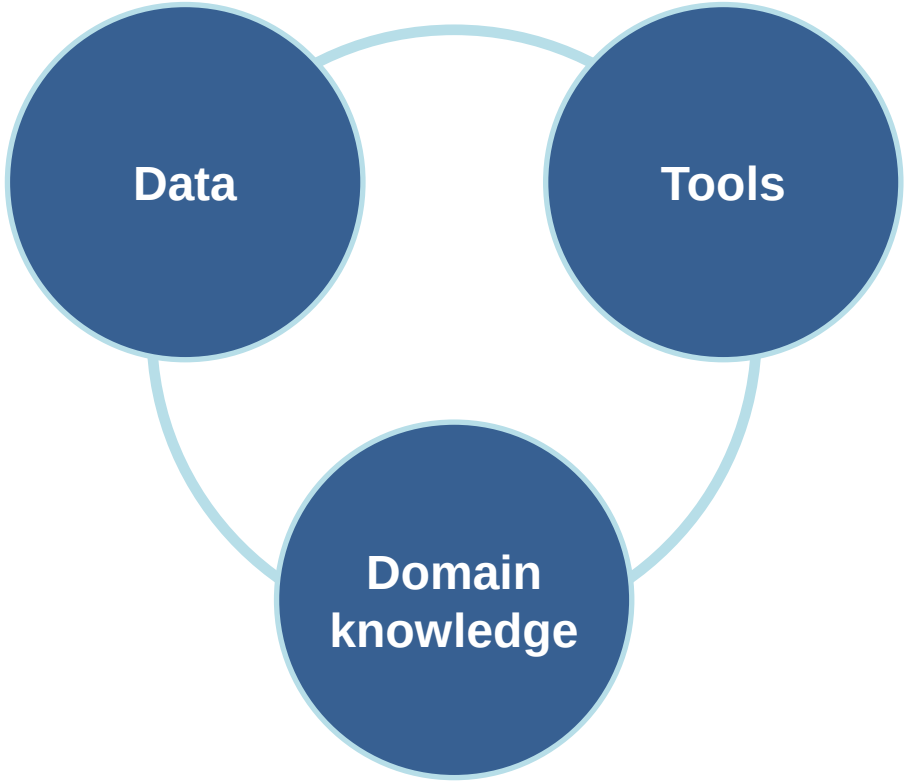


[Yin et al., 2023]

Brain areas contributing to predictions

Summary: MRI Data Analytics





MATLAB

python™

R