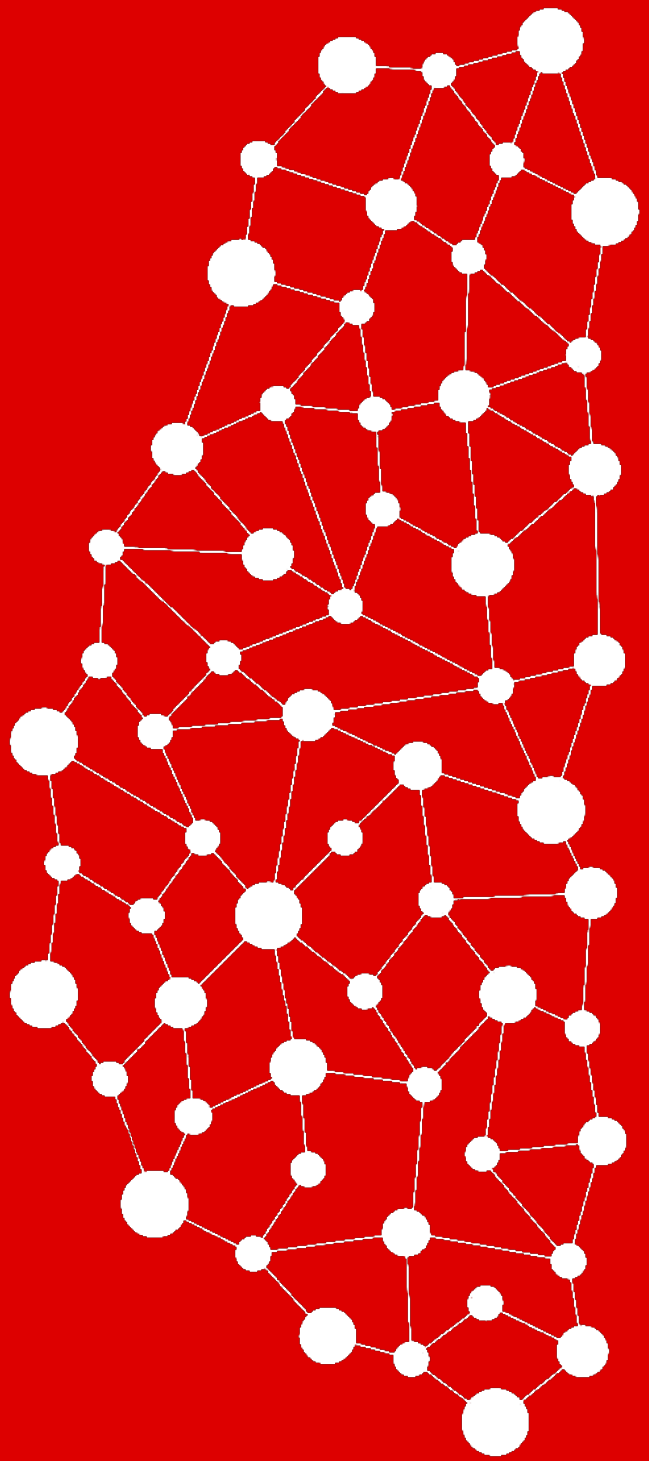
Exploring brain heterogeneity in neuropsychiatric patients with explainable artificial intelligence

Esten H. Leonardsen

Post-doc at the Department of Psychology, University of Oslo

Chief Scientific Officer, baba.vision

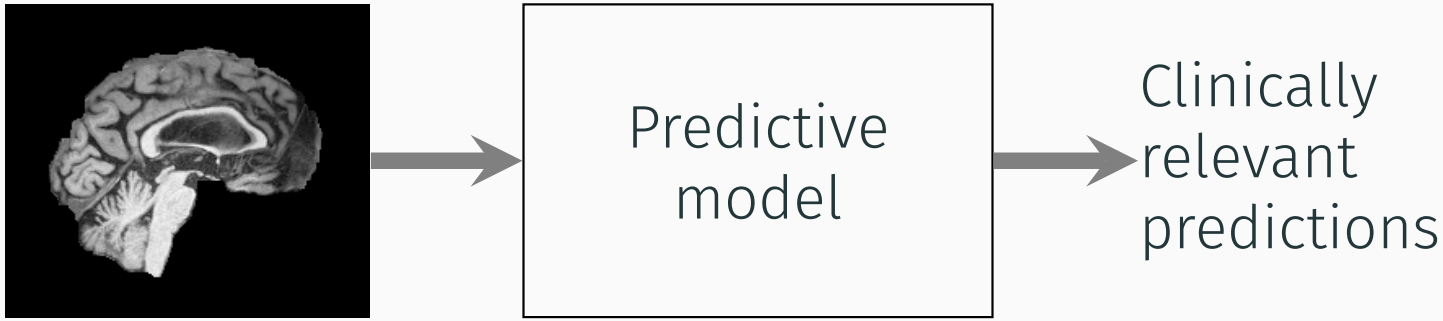


UNIVERSITY OF OSLO

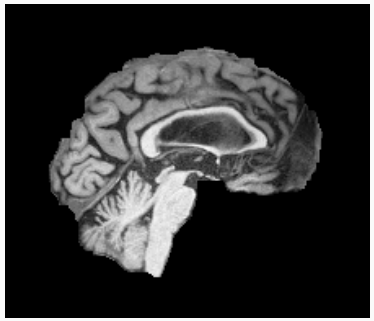
Outline

1. Background and motivation
2. Explainable dementia classification
3. Explainable brain age predictions

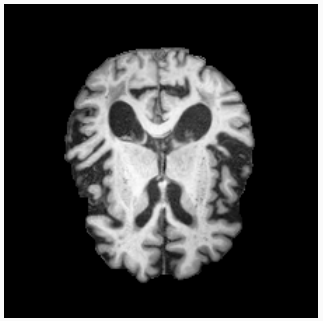
Background: Predictive clinical neuroscience



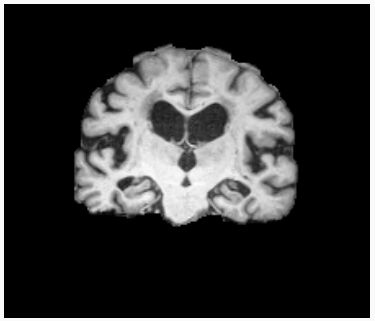
Background: Predictive clinical neuroscience



Side

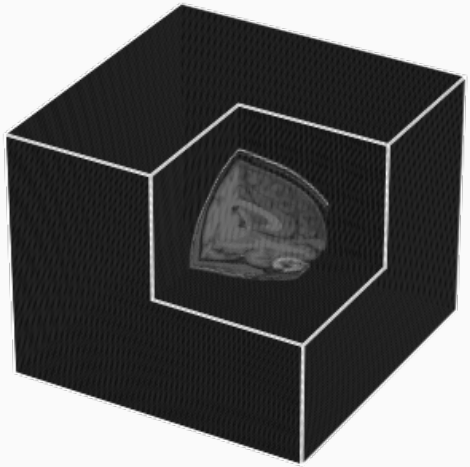


Above

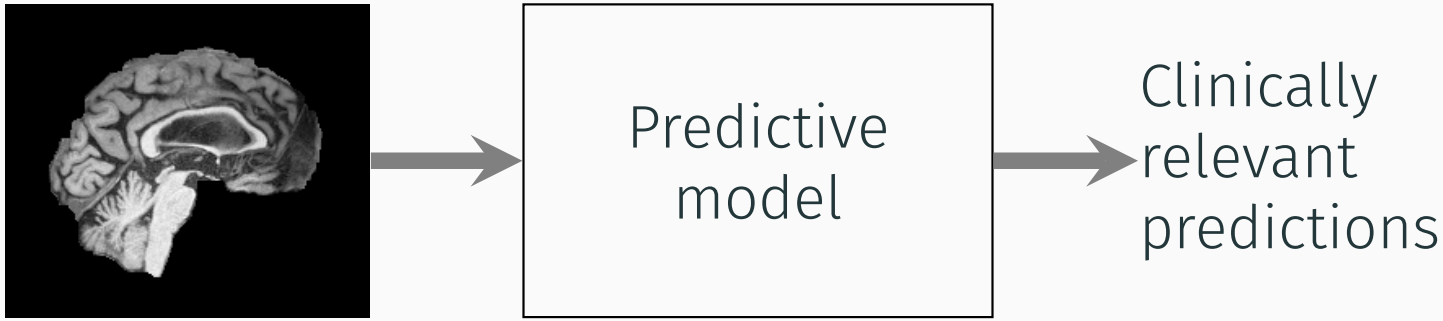


Front

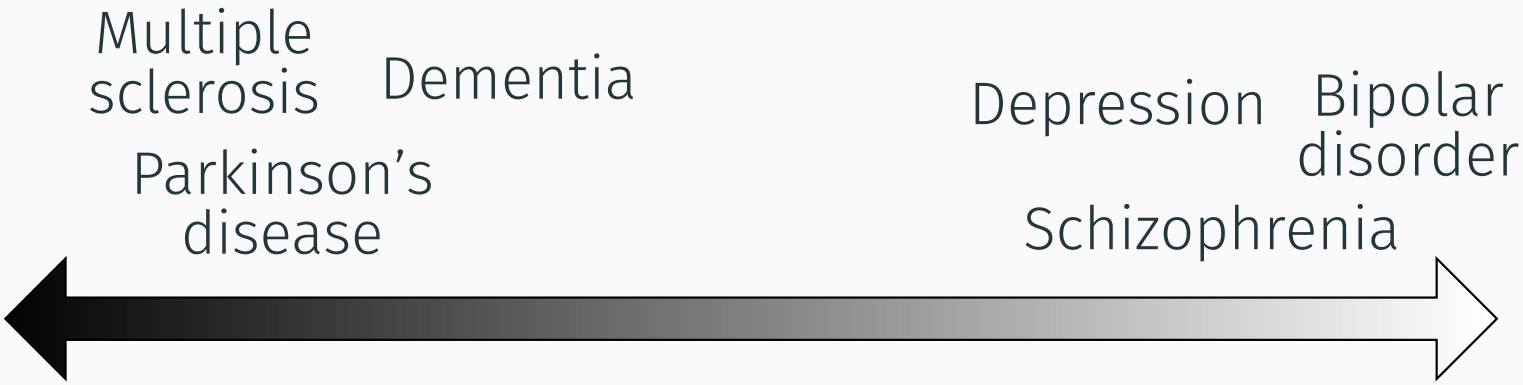
Structural Magnetic
Resonance Imaging (MRI) scans



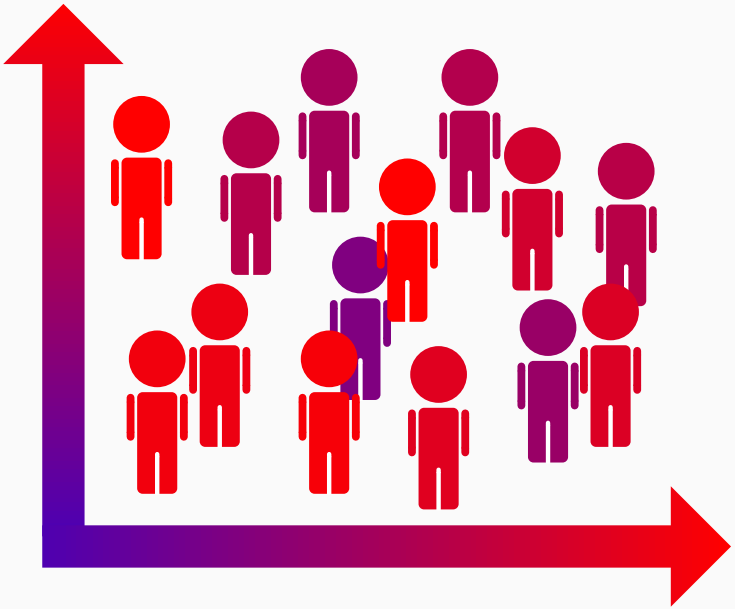
Background: Predictive clinical neuroscience



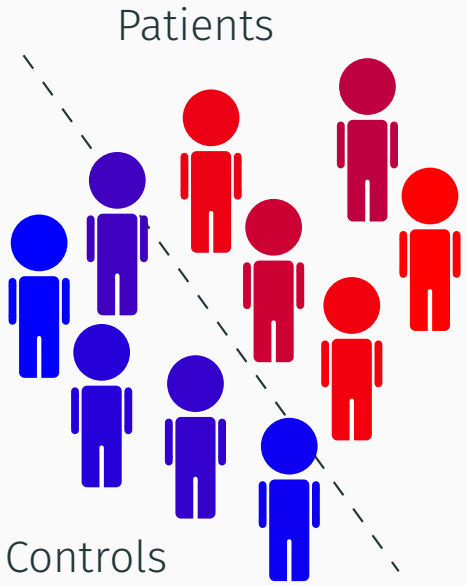
Background: Predictive clinical neuroscience



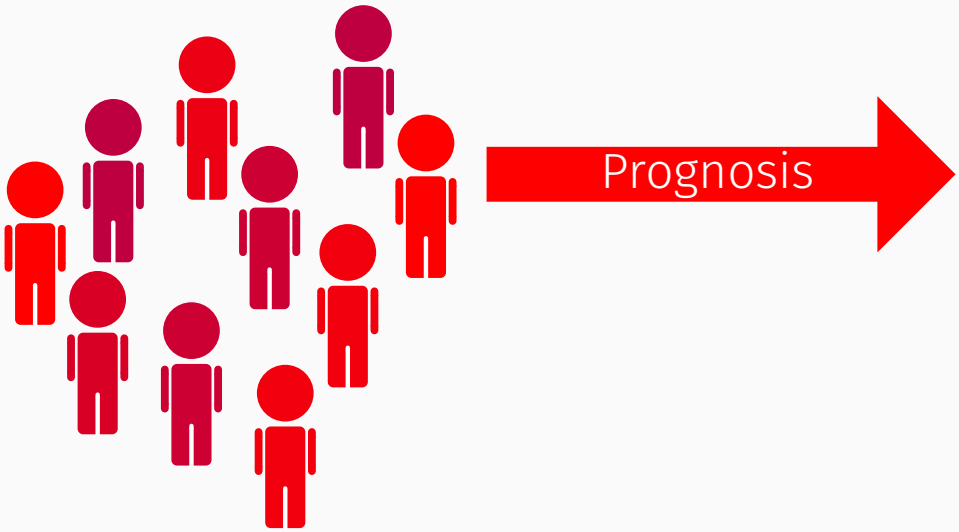
Background: Predictive clinical neuroscience



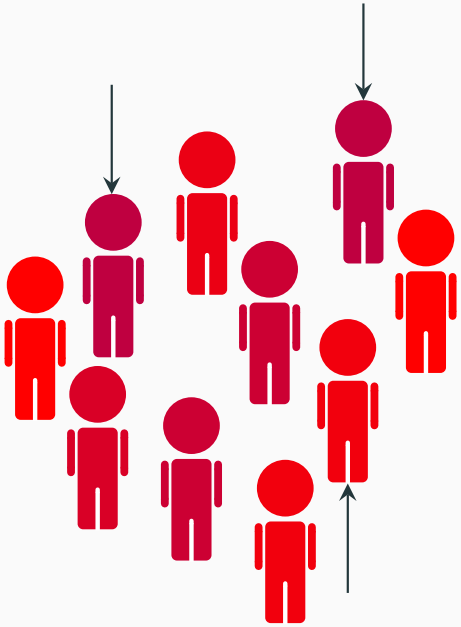
Background: Predictive clinical neuroscience



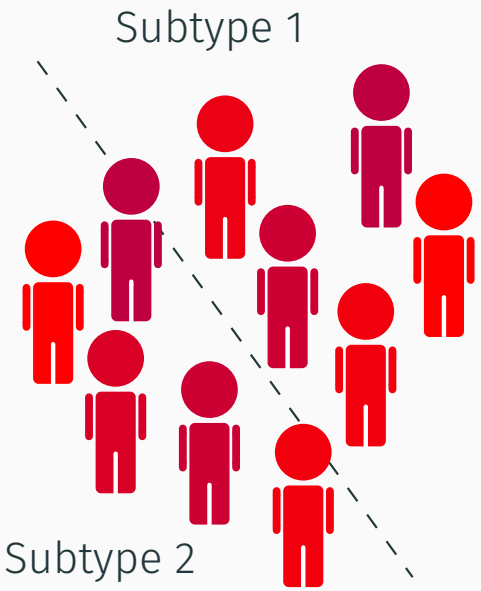
Background: Predictive clinical neuroscience



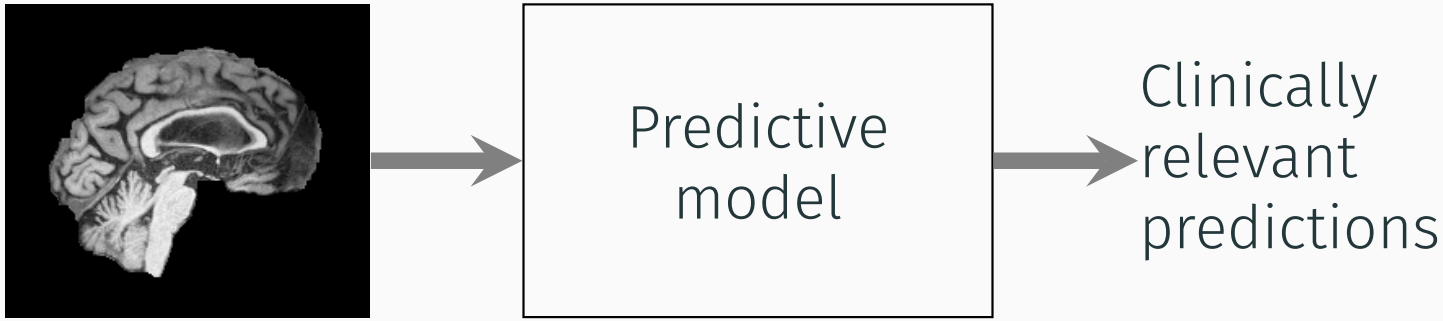
Background: Predictive clinical neuroscience



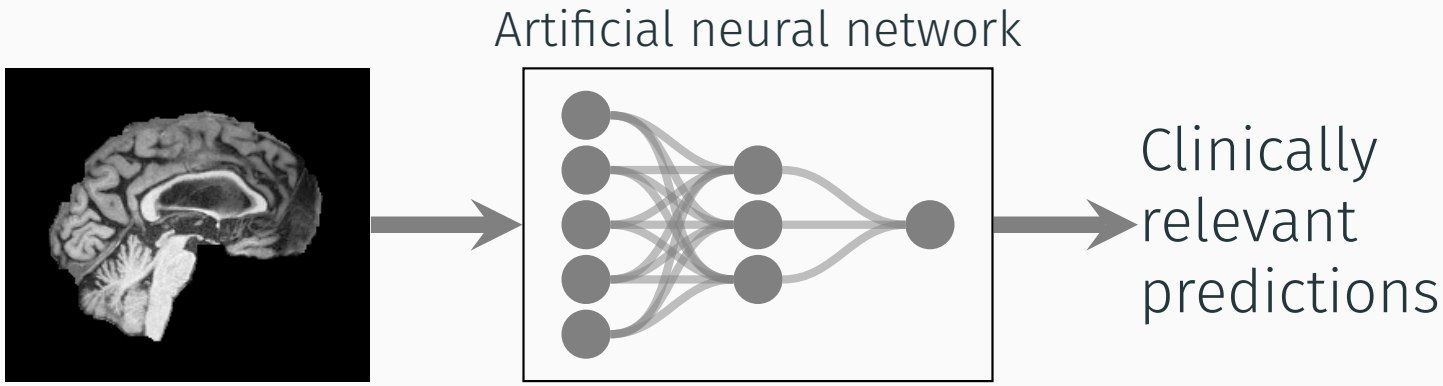
Background: Predictive clinical neuroscience



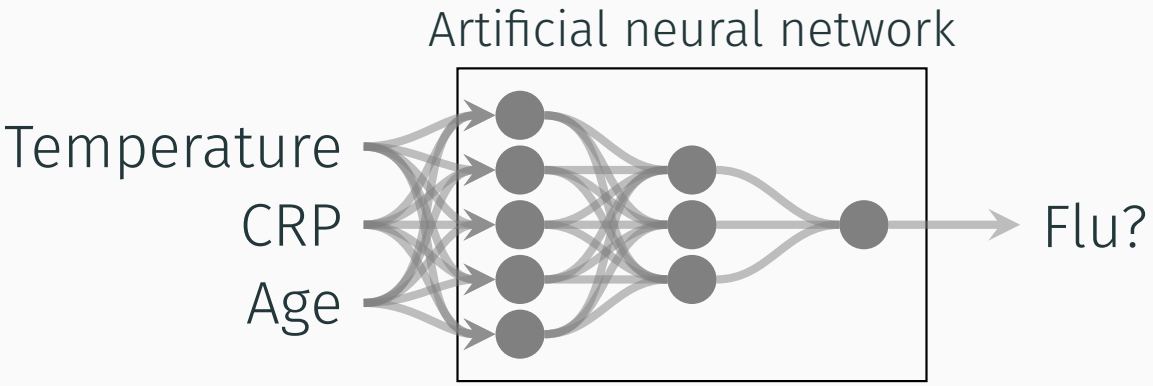
Background: Explainable artificial intelligence



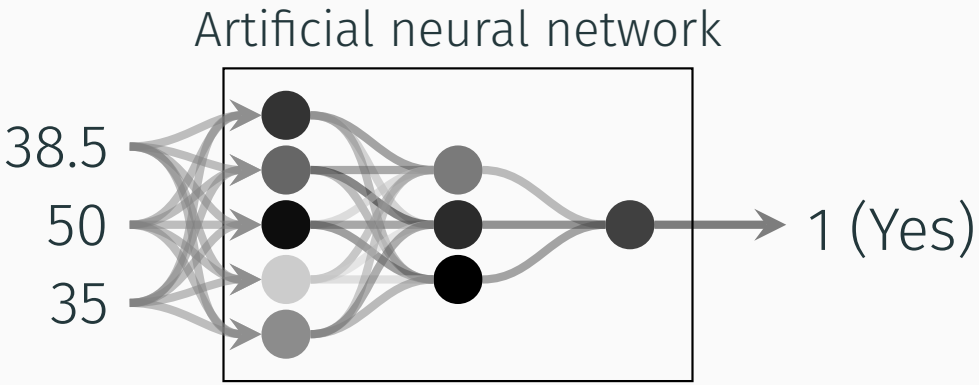
Background: Explainable artificial intelligence



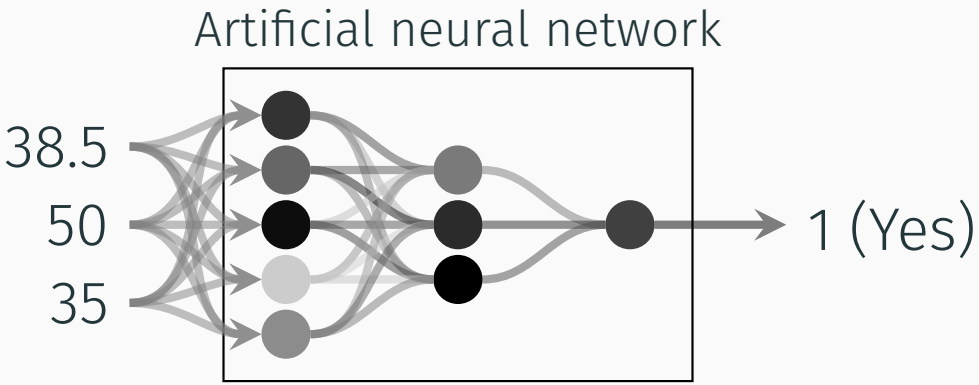
Background: Explainable artificial intelligence

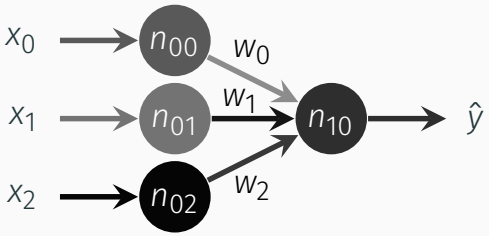


Background: Explainable artificial intelligence



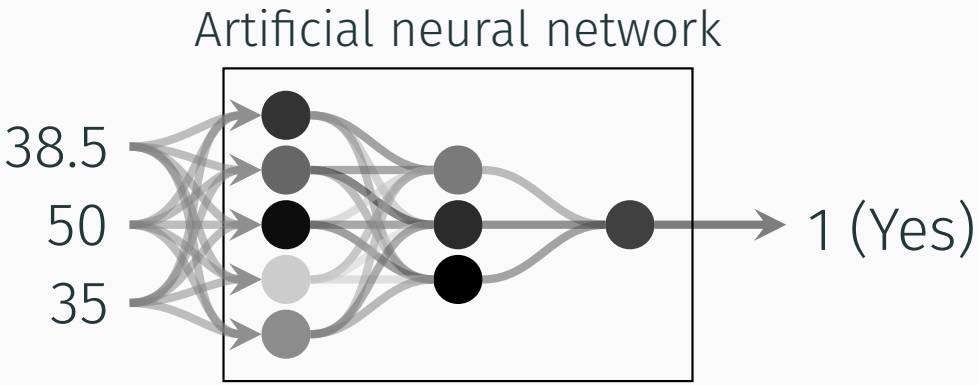
Background: Explainable artificial intelligence

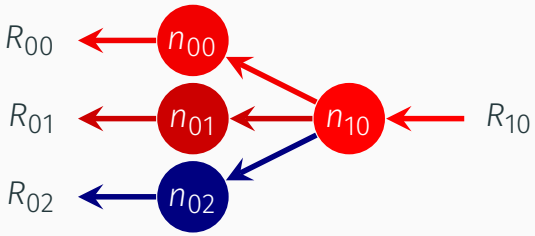




$$\hat{y} = f\left(\sum_{i}^{N} w_i \cdot n_{0i}\right)$$

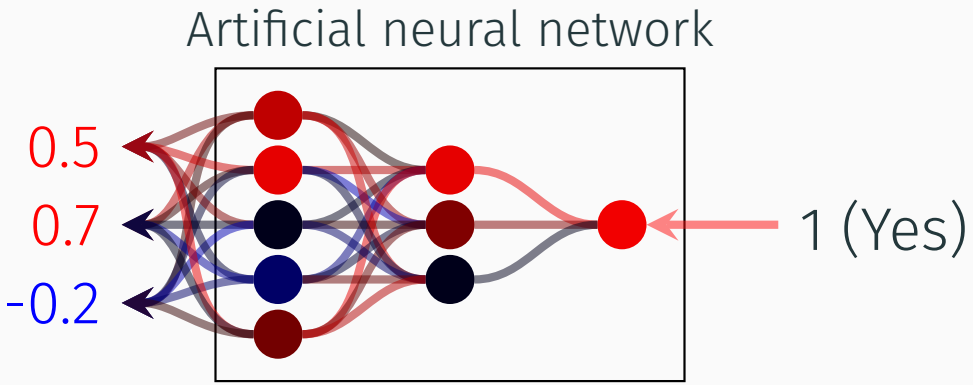
Background: Explainable artificial intelligence

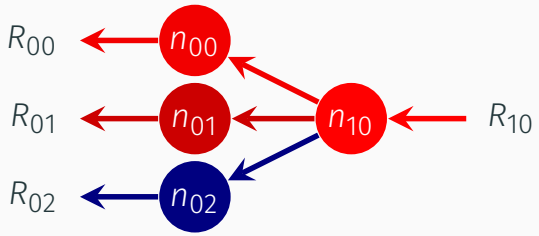




$$R_{0i} = \sum_j \frac{n_{0i} w_i}{\sum_k n_{0k} w_k} R_{1j}$$

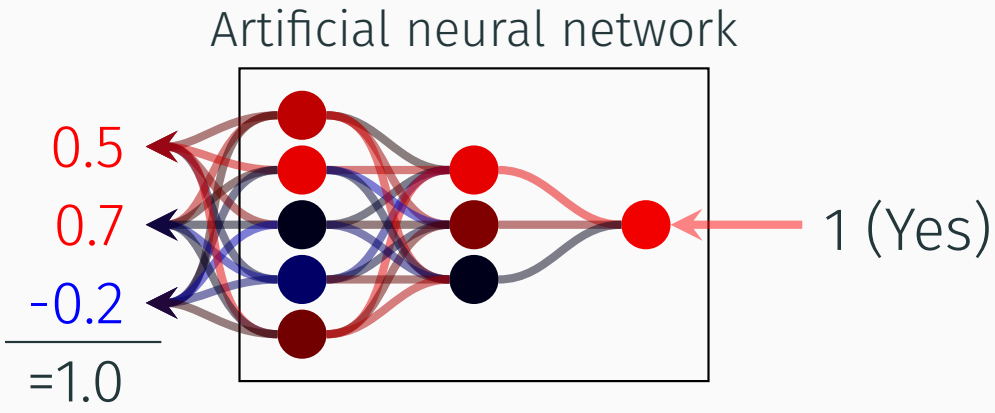
Background: Explainable artificial intelligence

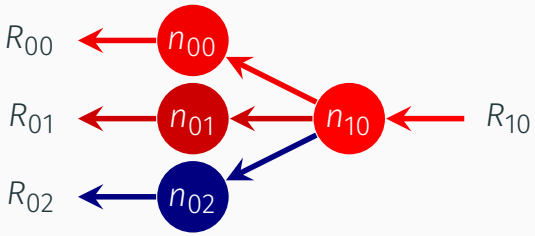




$$R_{0i} = \sum_j \frac{n_{0i} w_i}{\sum_k n_{0k} w_k} R_{1j}$$

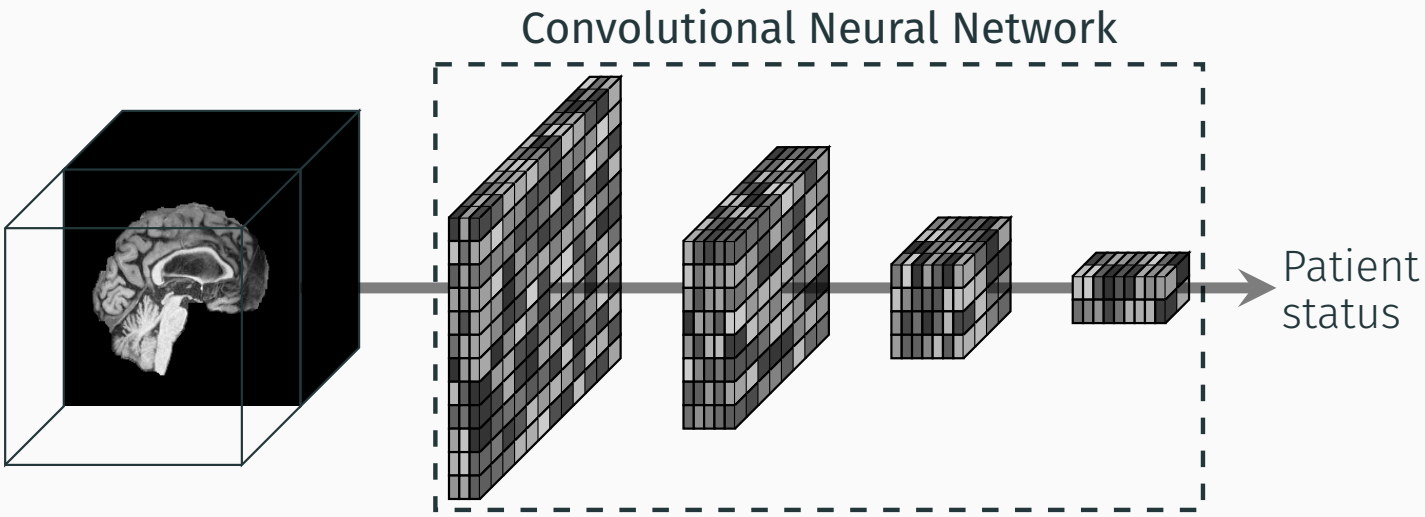
Background: Explainable artificial intelligence

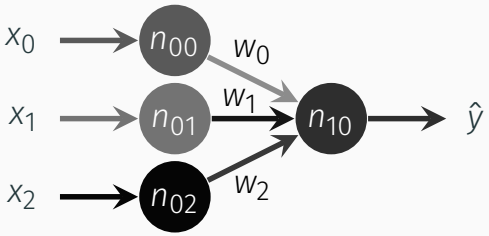




$$R_{0i} = \sum_j \frac{n_{0i} w_i}{\sum_k n_{0k} w_k} R_{1j}$$

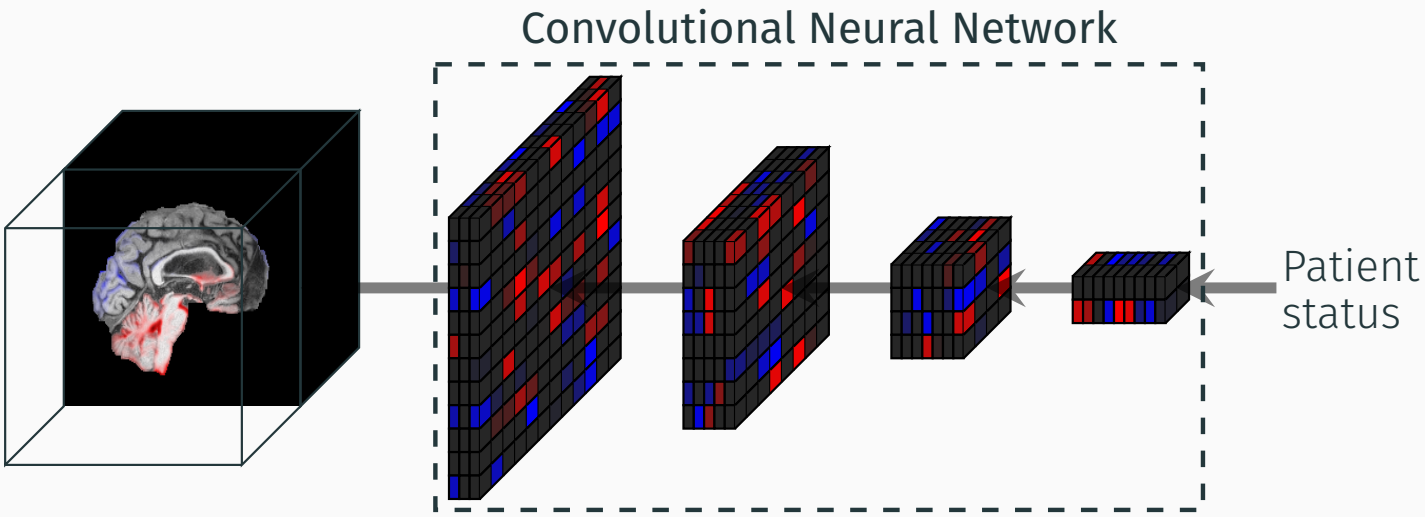
Background: Explainable artificial intelligence

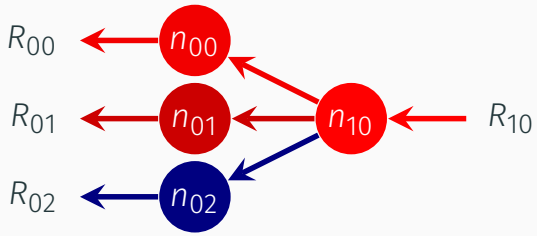




$$\hat{y} = f\left(\sum_{i}^{N} w_i \cdot n_{0i}\right)$$

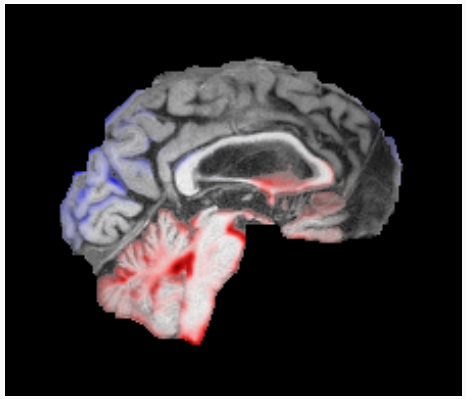
Background: Explainable artificial intelligence

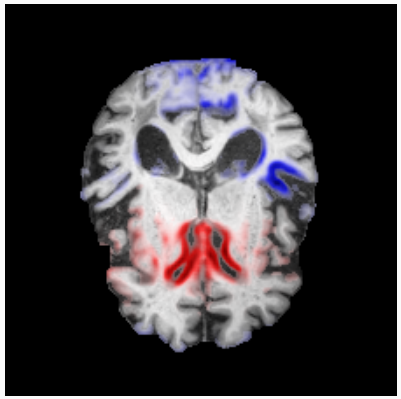


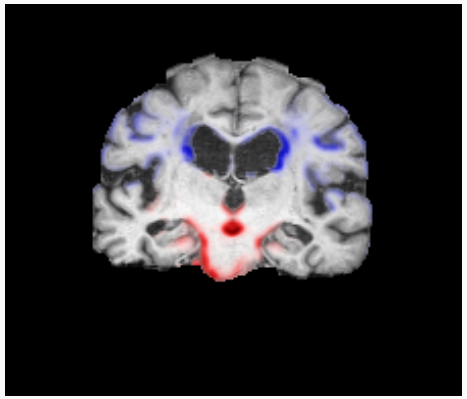


$$R_{0i} = \sum_j \frac{n_{0i} w_i}{\sum_k n_{0k} w_k} R_{1j}$$

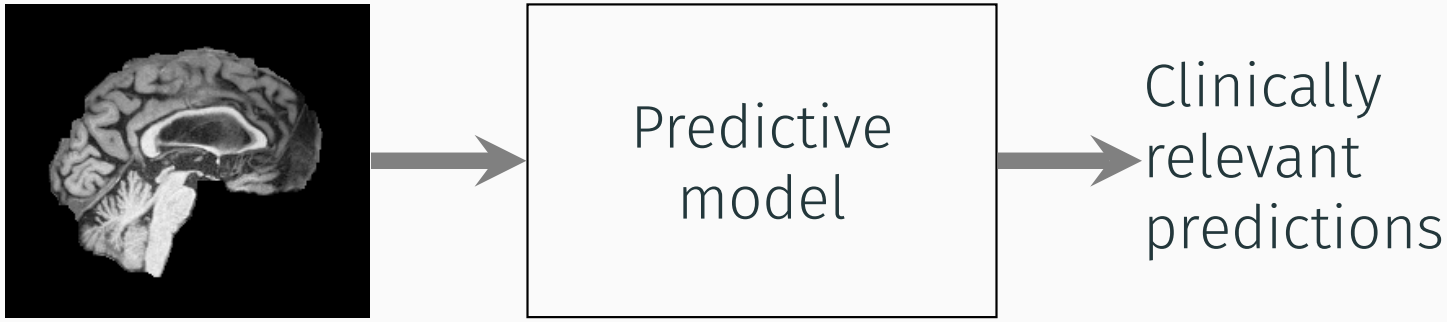
Background: Explainable artificial intelligence



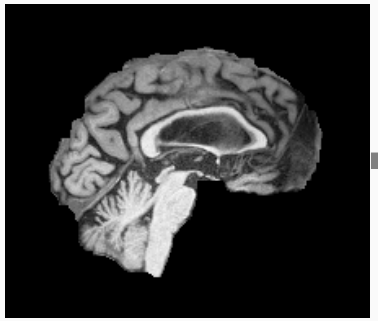




Background: Conceptualization

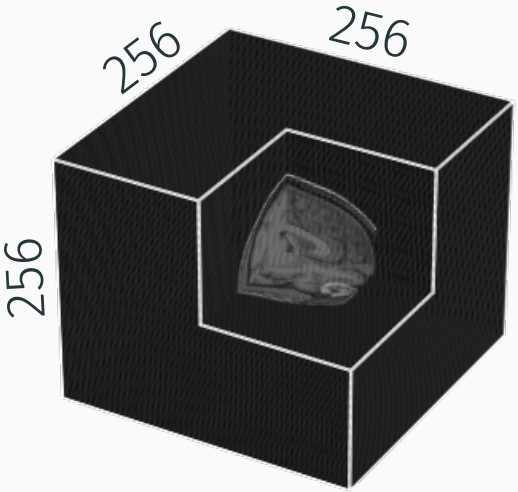


Background: Conceptualization

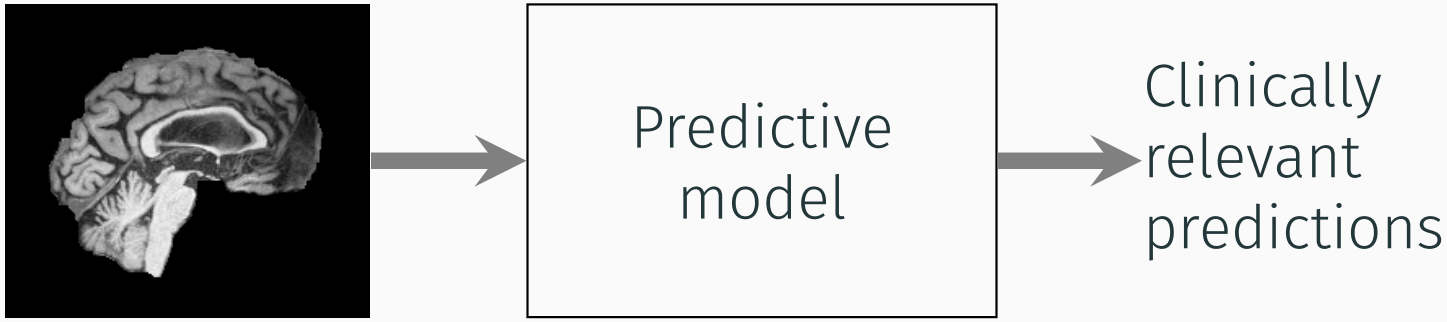


Predictive model

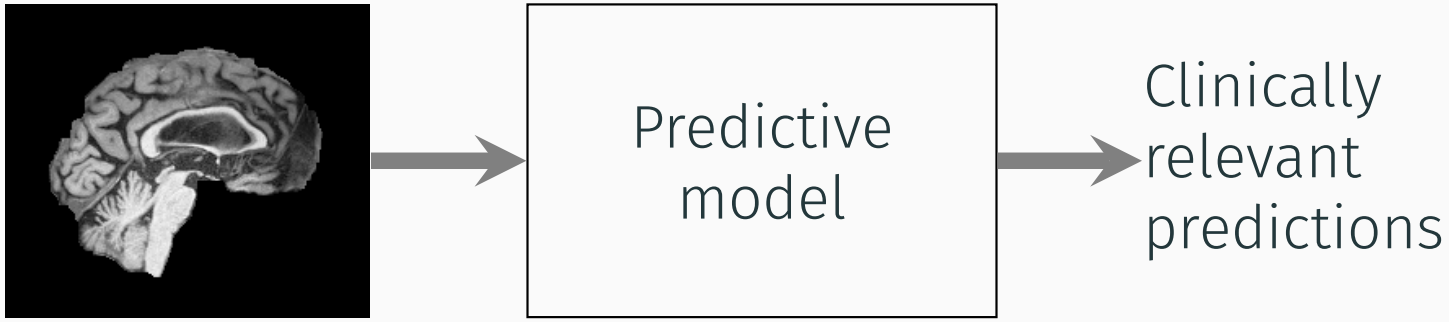
Clinically relevant predictions

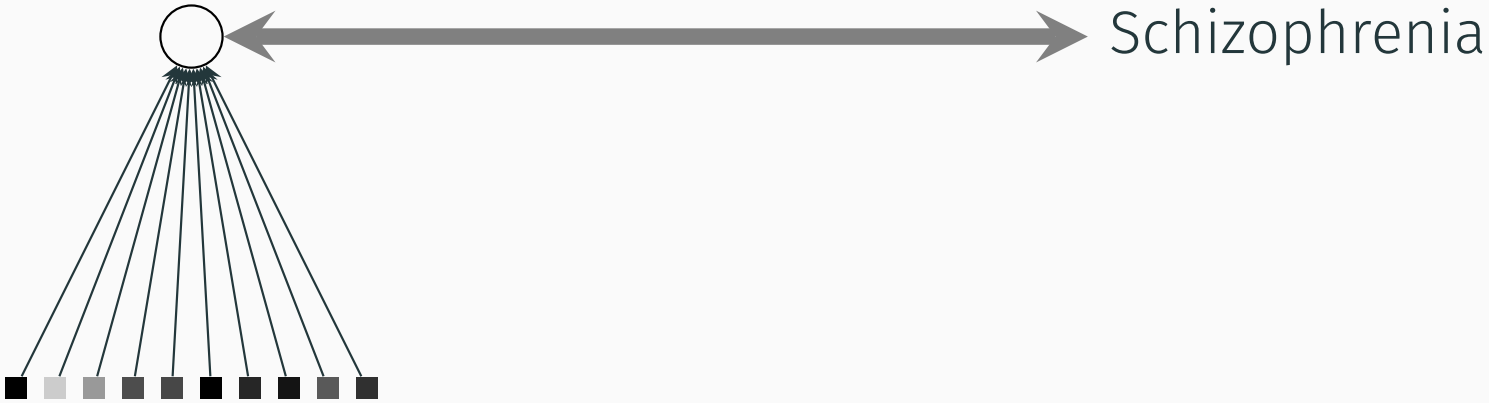


Background: Conceptualization



Background: Conceptualization



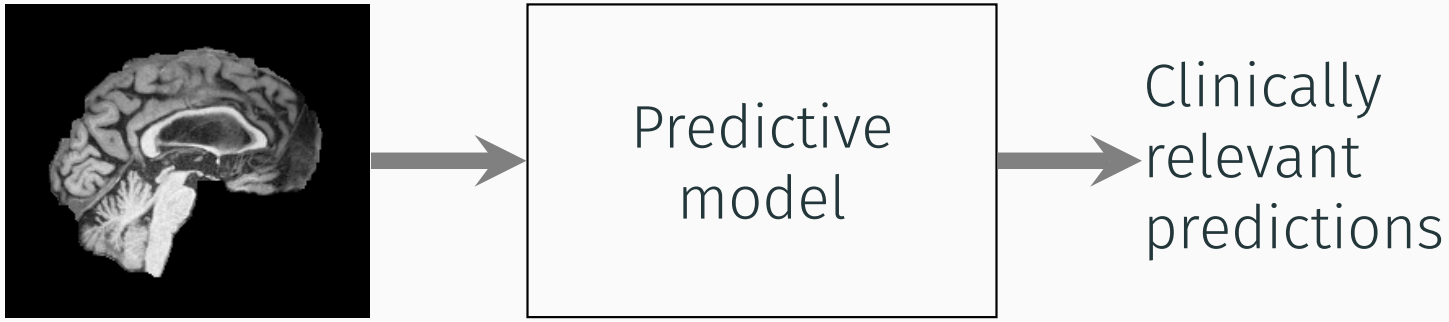


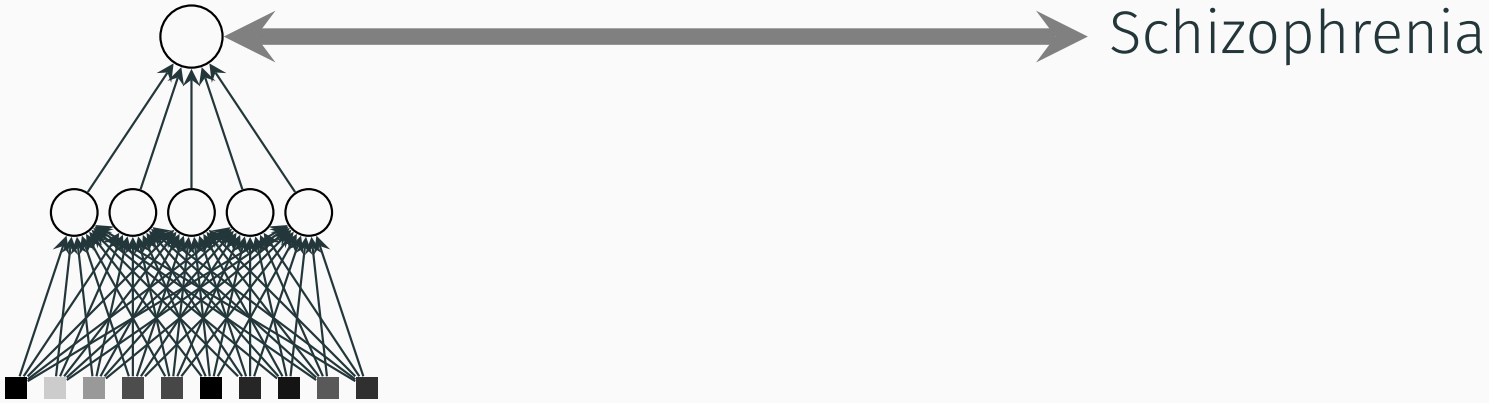
Background: Conceptualization

"Despite considerable heterogeneity at the regional level, deviations were often coupled to common functional circuits and networks"

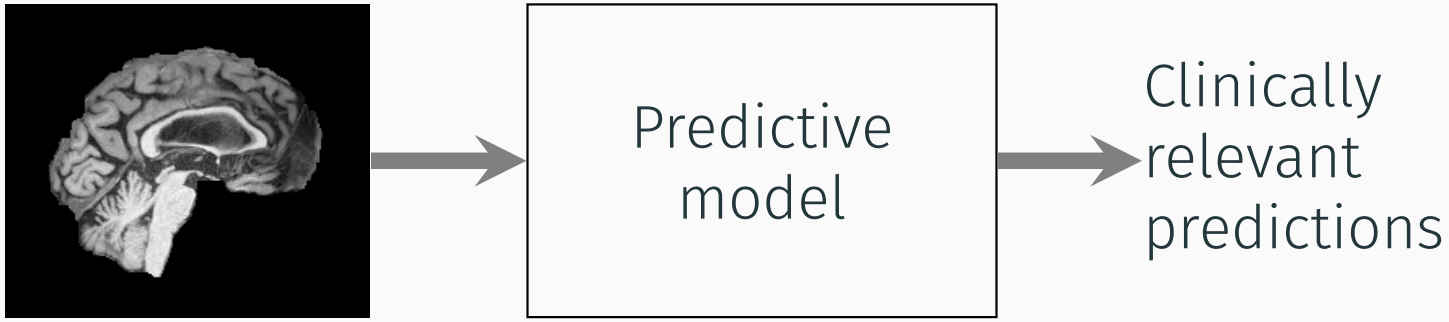
Regional, circuit and network heterogeneity of brain abnormalities in psychiatric disorders
Segal, A. et al., *Nature Neuroscience* (2023)

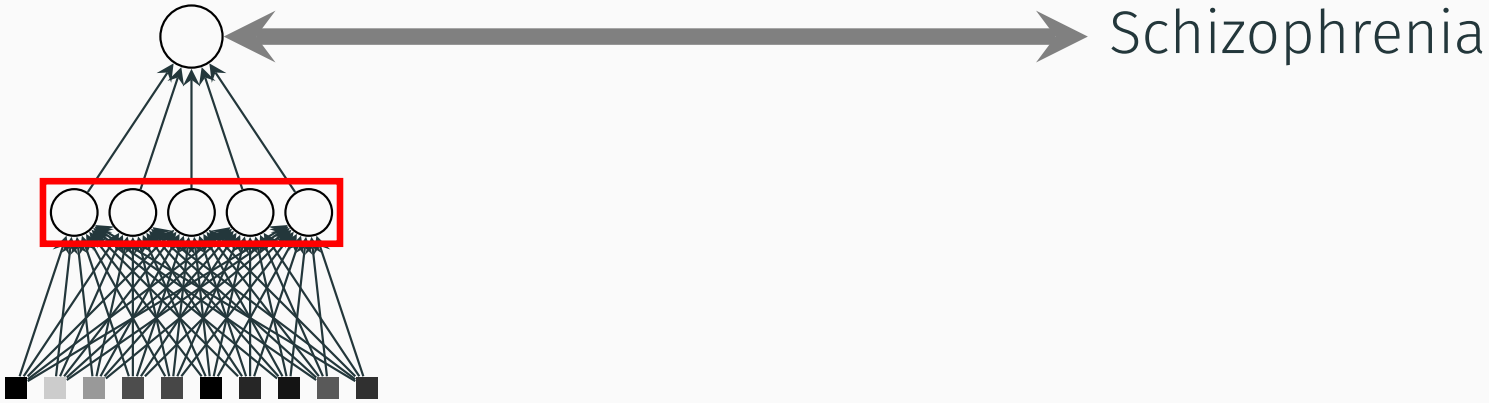
Background: Conceptualization



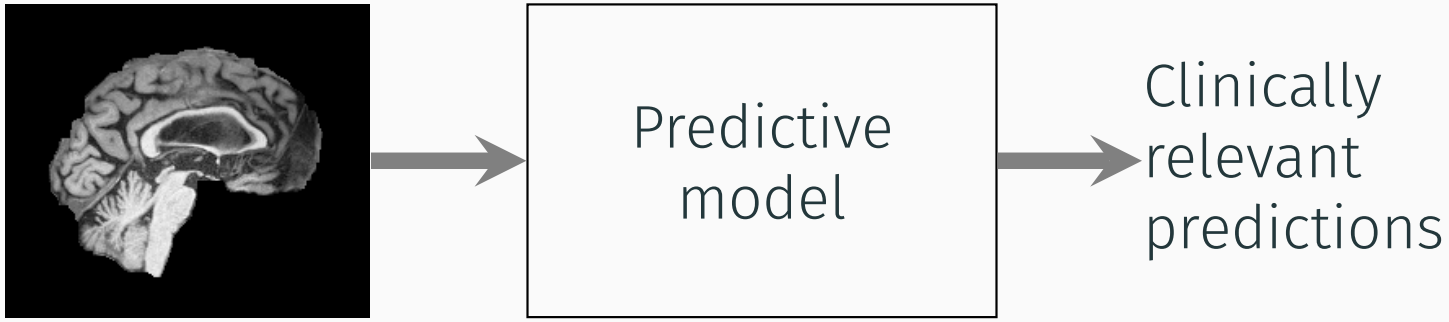


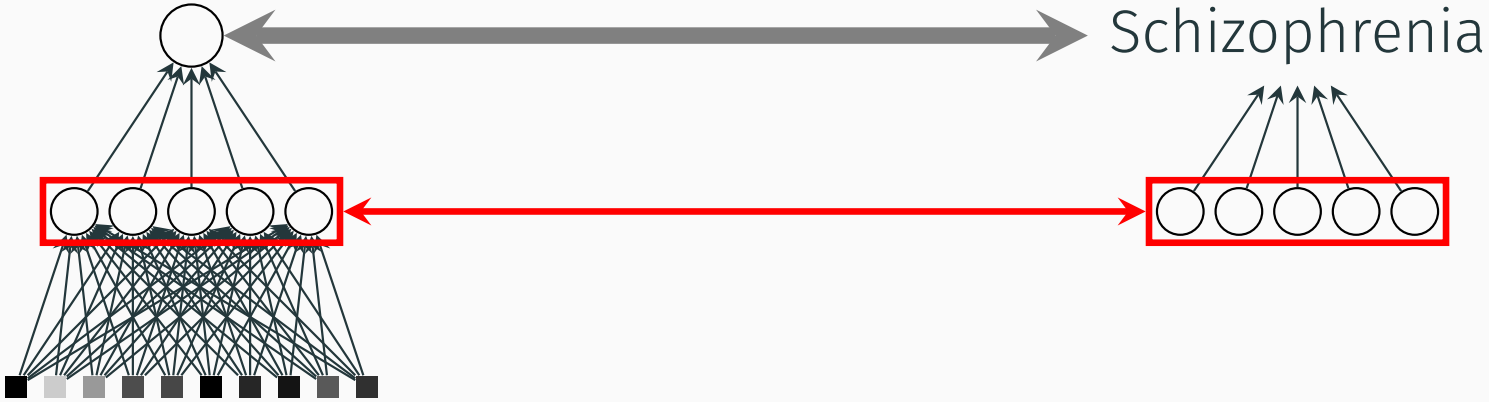
Background: Conceptualization





Background: Conceptualization





Background: Conceptualization

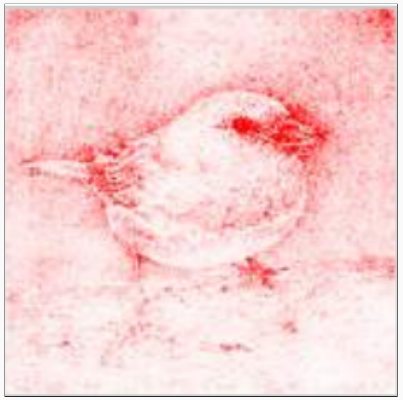
"We propose explanation space as a powerful embedding to facilitate detection of latent disease subtypes, [...]. Transforming from feature space to explanation space should not be seen in competition to dimensionality reduction, but rather as a complimentary processing step"

Inferring disease subtypes from clusters in explanation space
Schulz, MA. et al., *Scientific Reports* (2020)

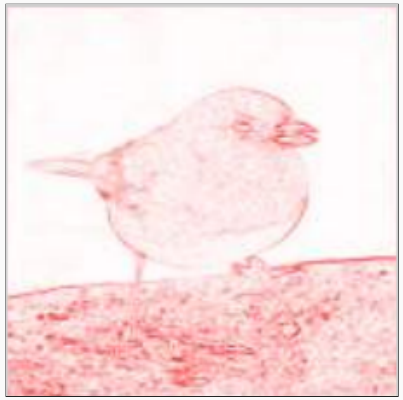
Background: Conceptualization

Input

Explanation



Edge detector

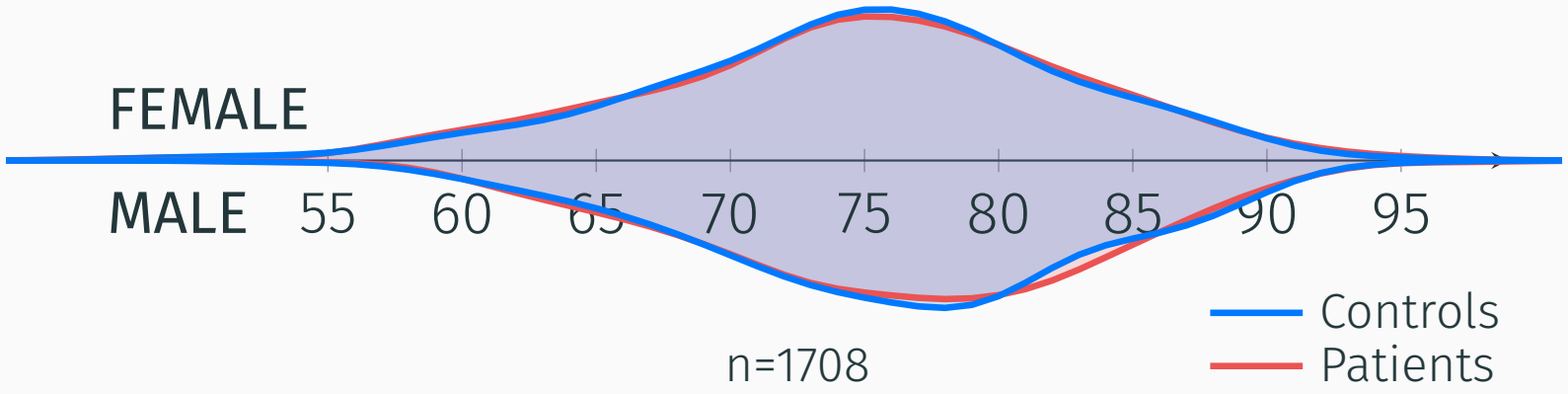


Sanity Checks for Saliency Maps
Adebayo, J. et al., *preprint at arXiv* (2018)

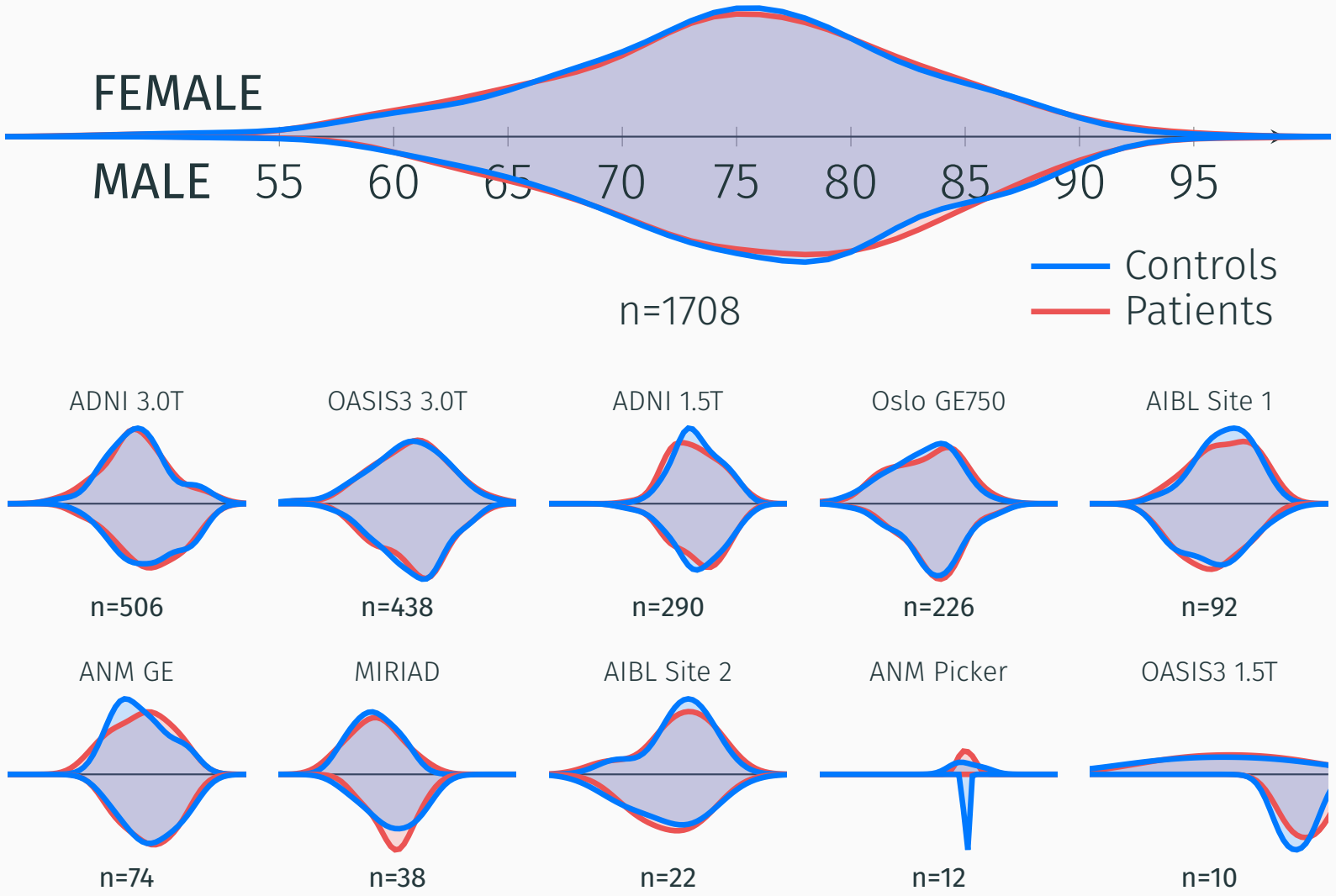
Explainable dementia classification

UNIVERSITY
OF OSLO

Explainable dementia classification: Dataset



Explainable dementia classification: Dataset

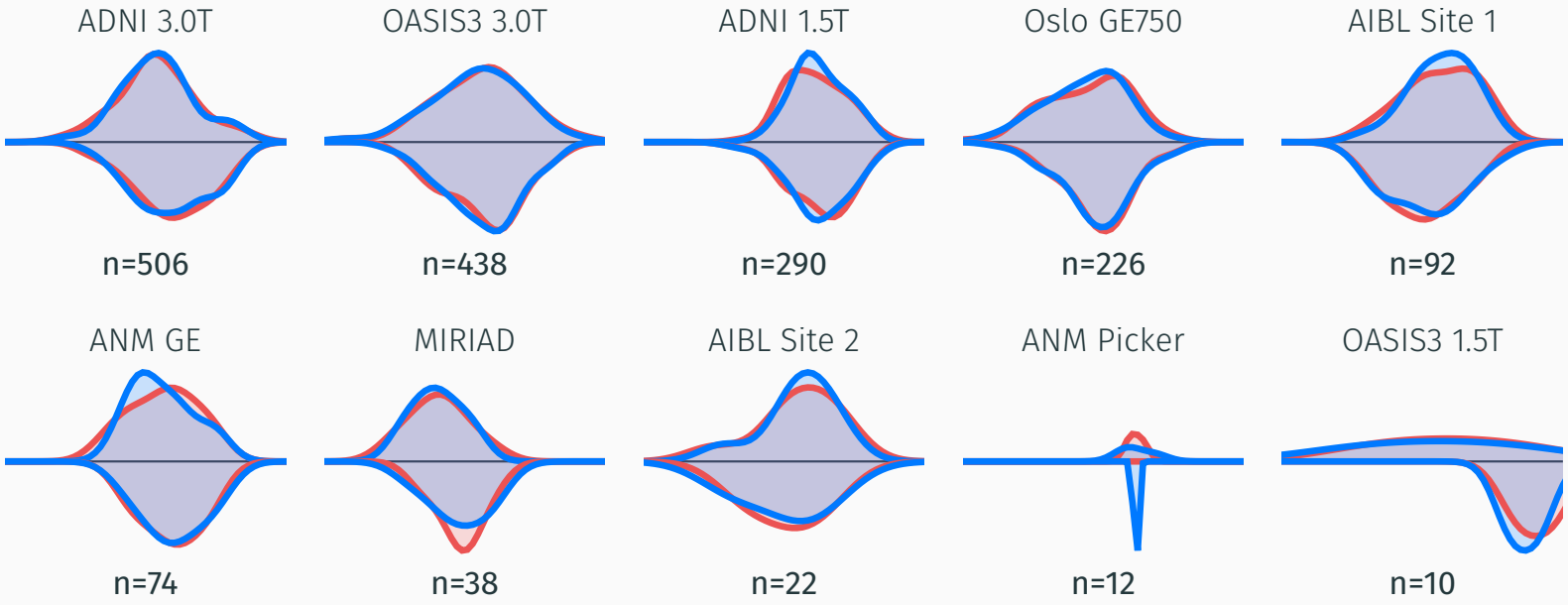


Explainable dementia classification: Dataset

ADNI:
Probable
Alzheimer's disease

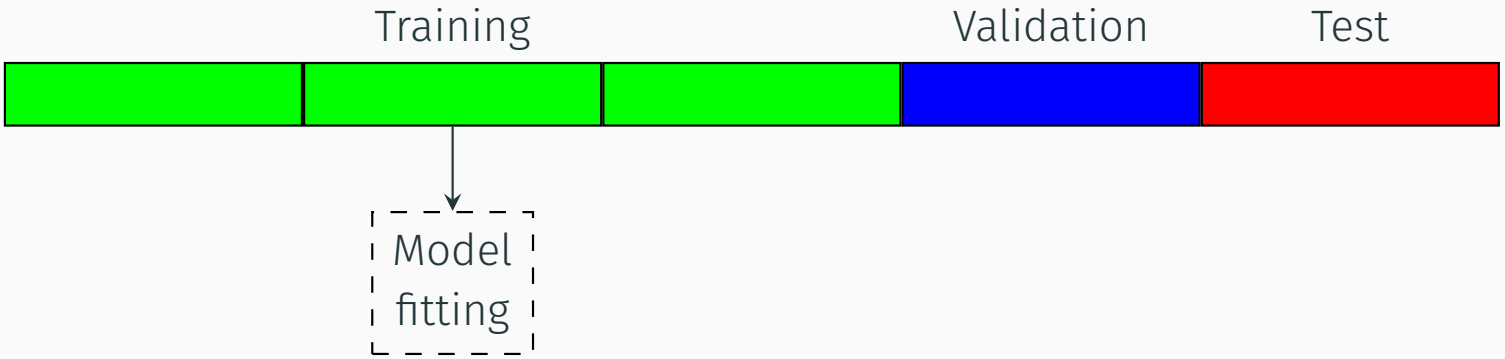
OASIS3:
Dementia

Oslo:
Alzheimer's disease,
Vascular dementia,
Unspecified dementia

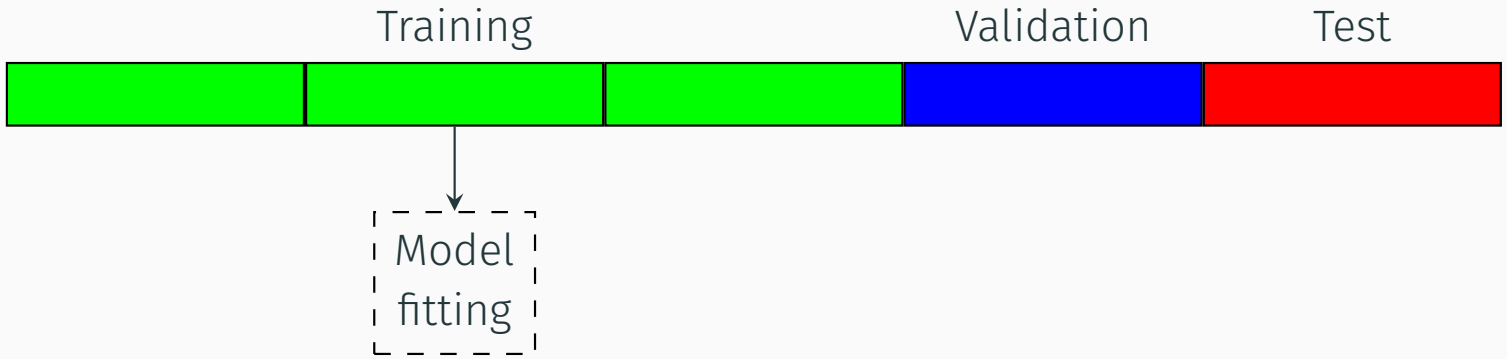


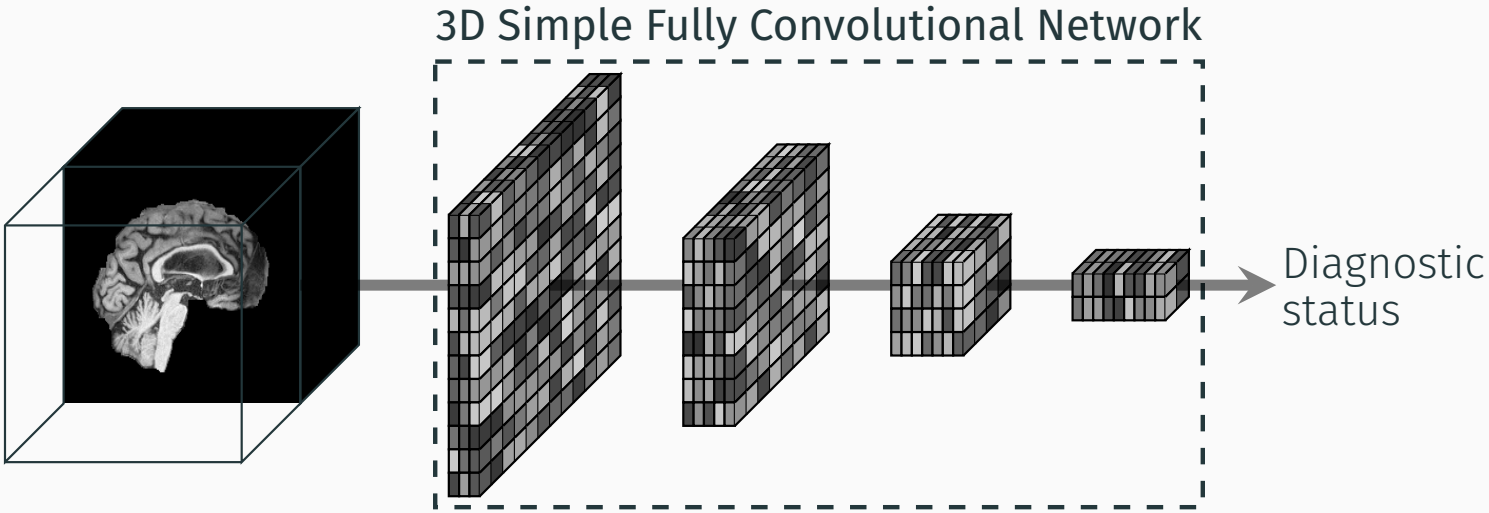
Explainable dementia classification: Modelling

Explainable dementia classification: Modelling

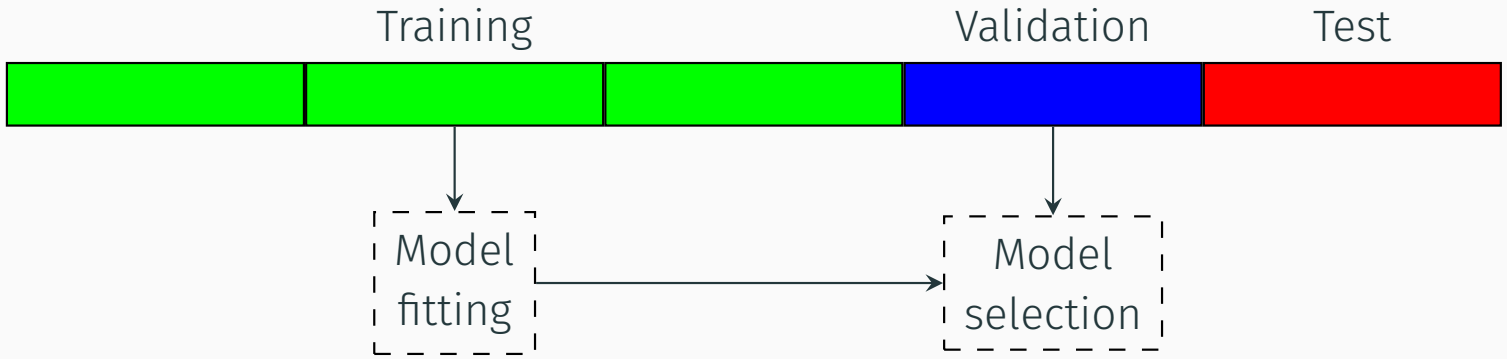


Explainable dementia classification: Modelling

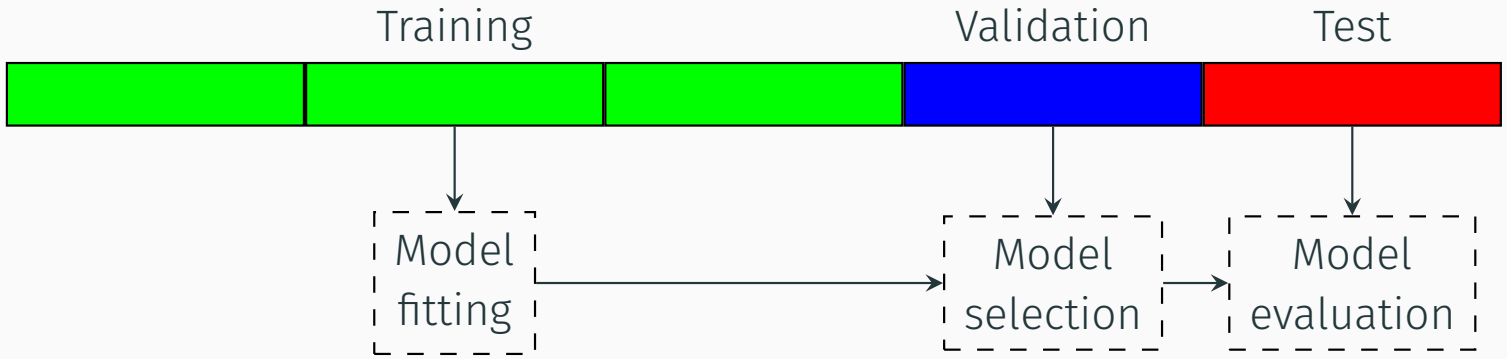


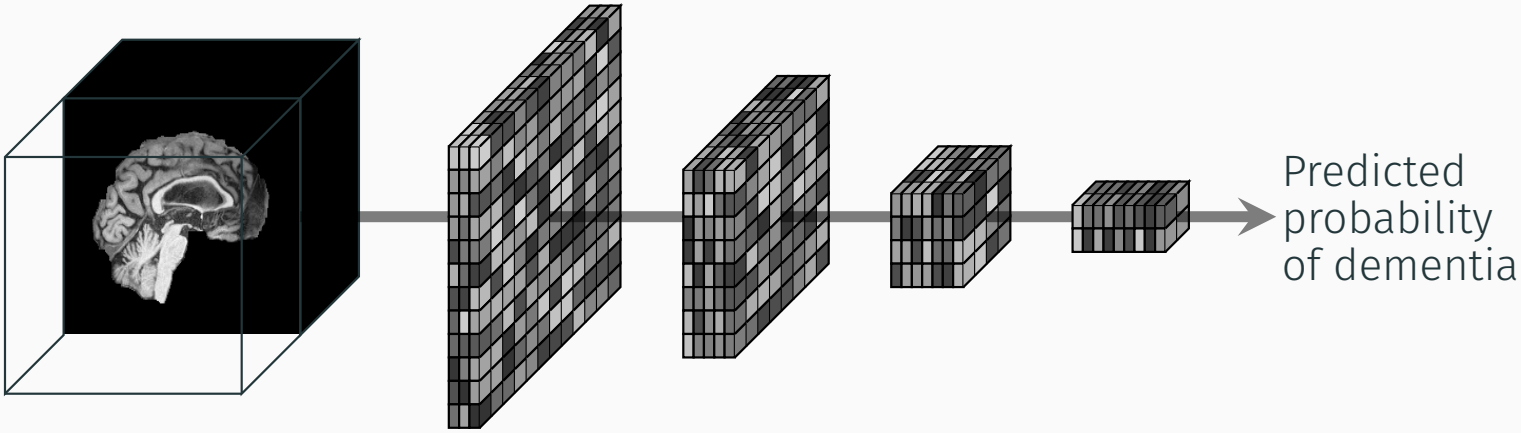


Explainable dementia classification: Modelling

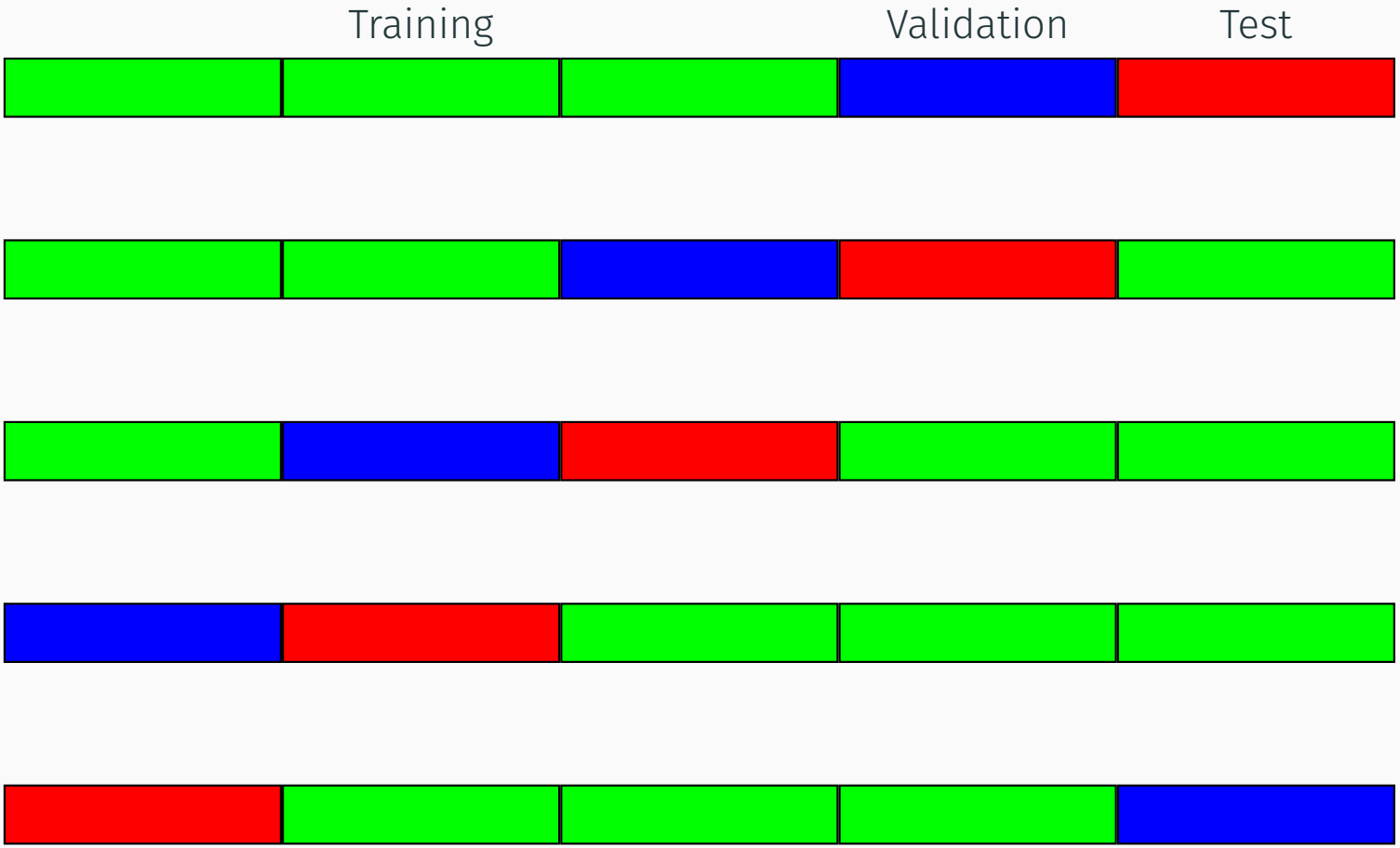


Explainable dementia classification: Modelling

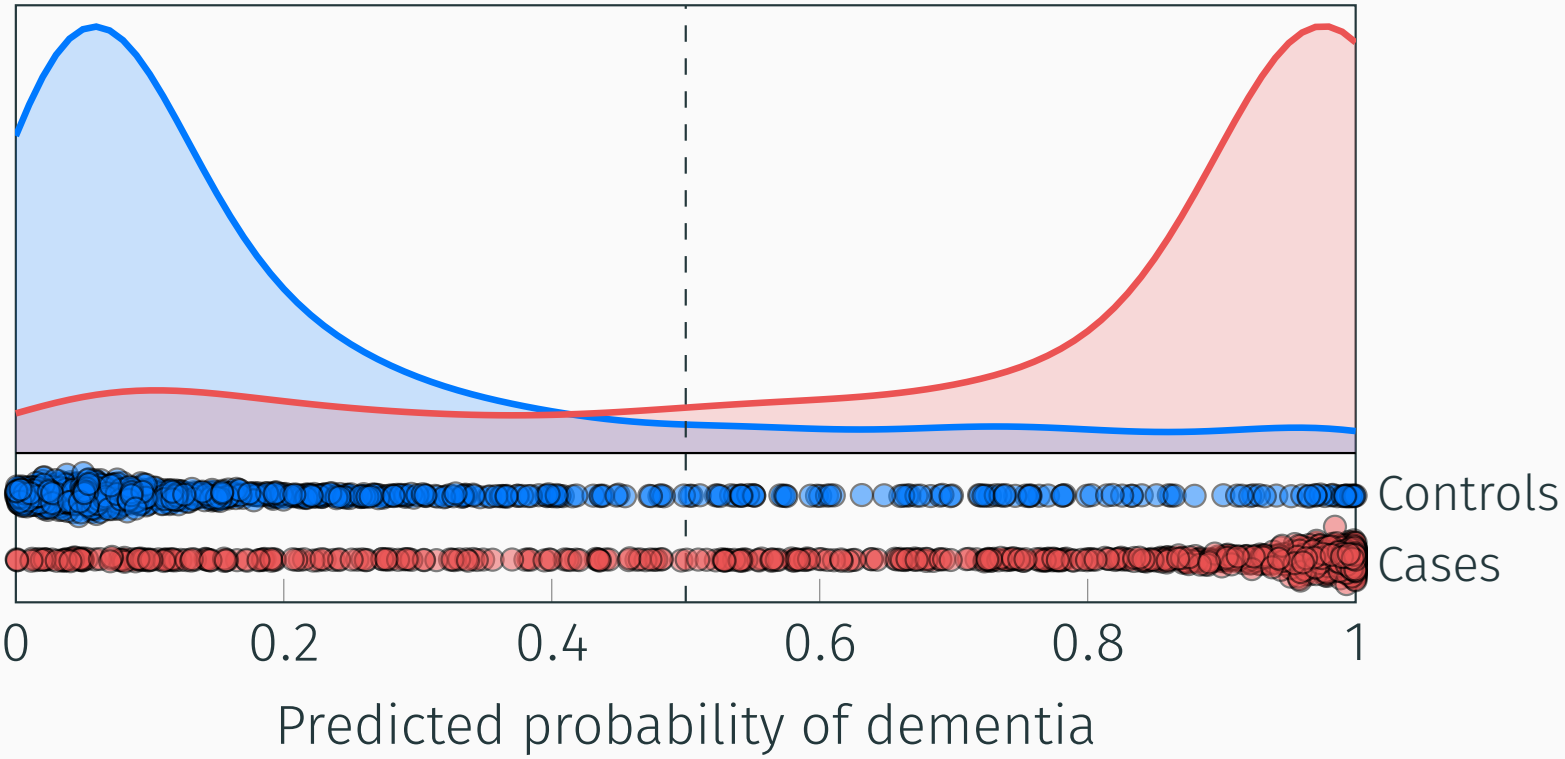




Explainable dementia classification: Modelling

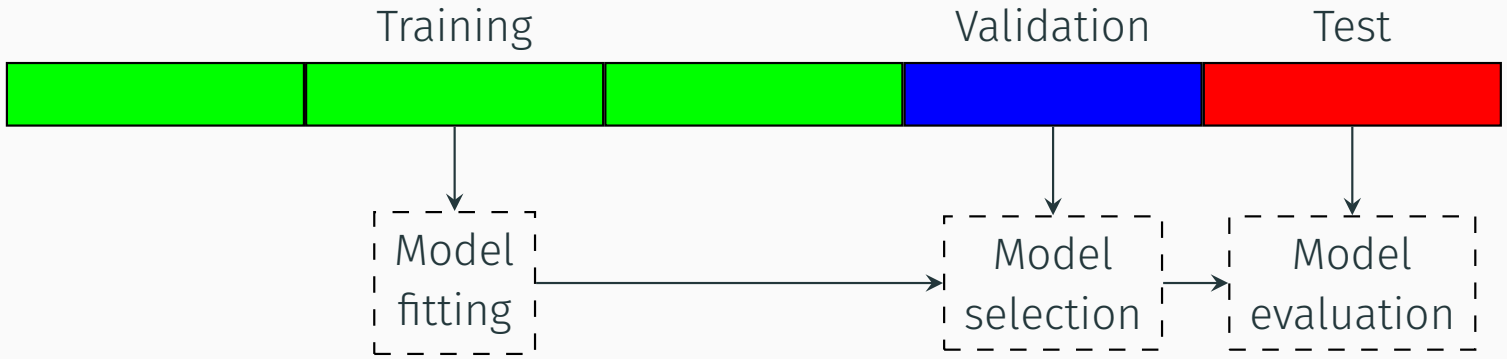


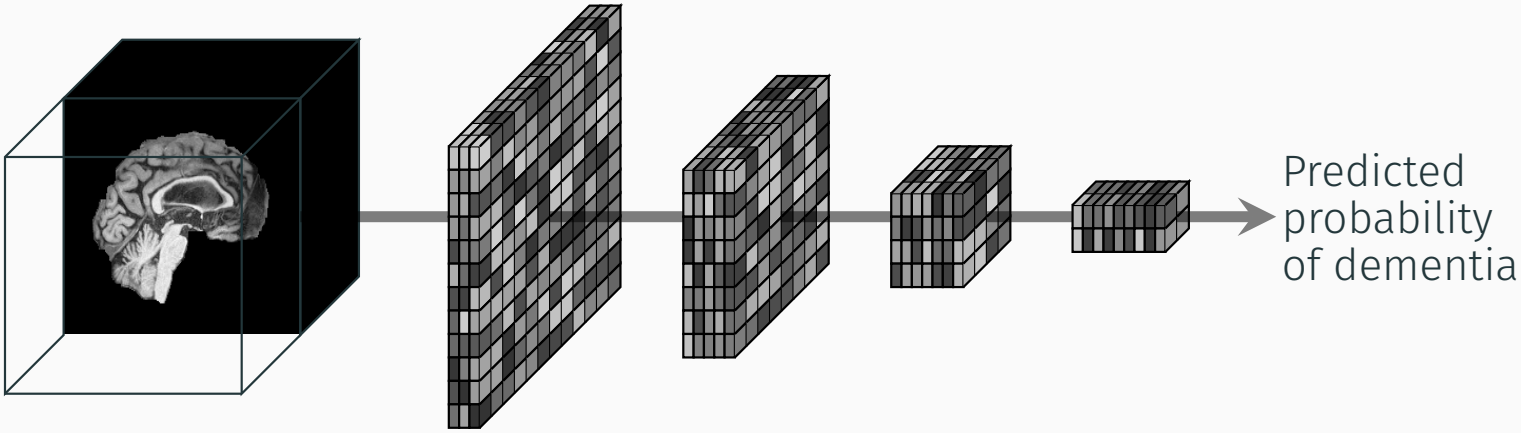
Explainable dementia classification: Modelling



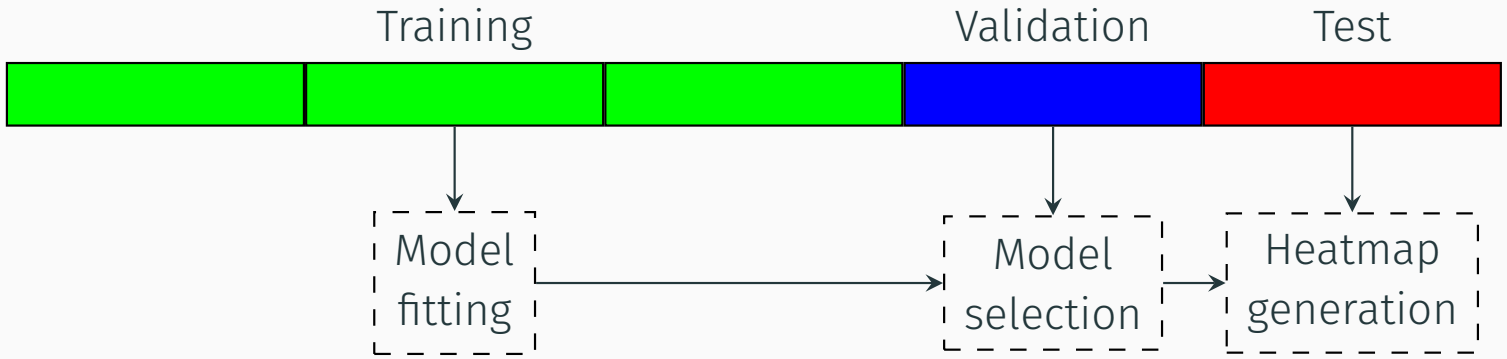
AUC=0.91, balanced accuracy=85%

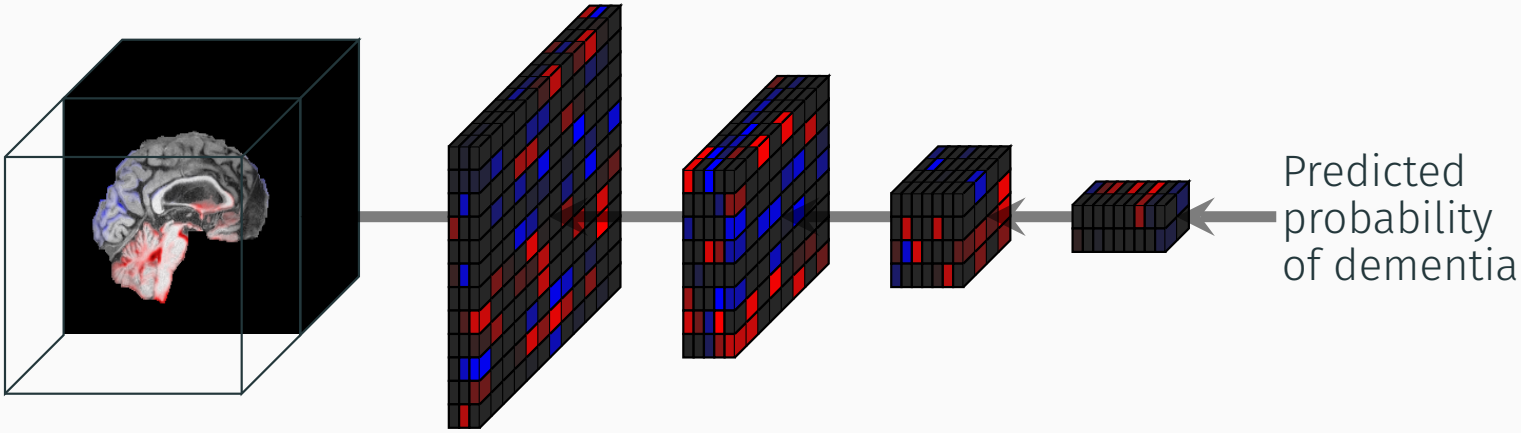
Explainable dementia classification: Modelling



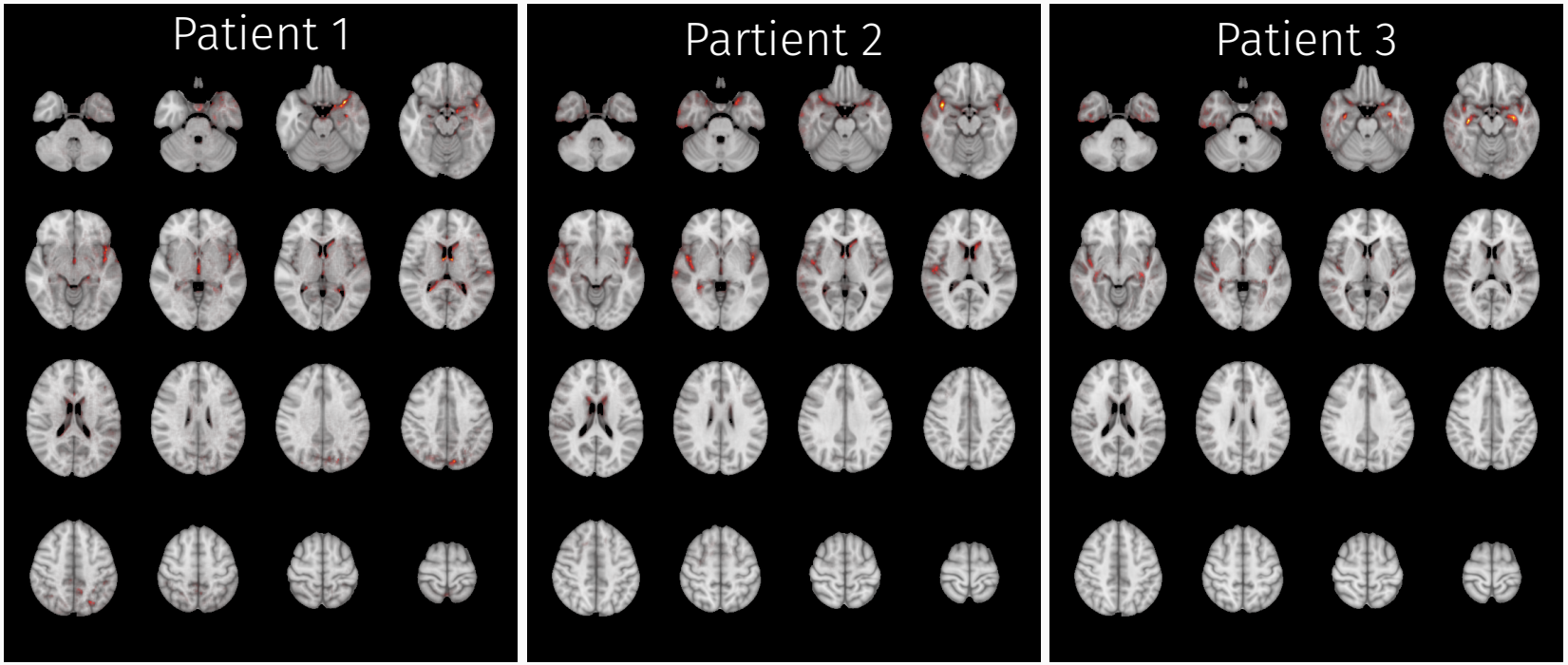


Explainable dementia classification: Modelling



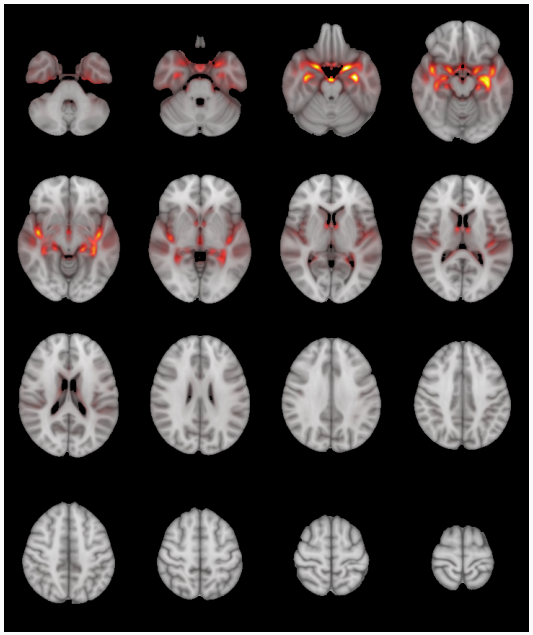


Explainable dementia classification: Validation



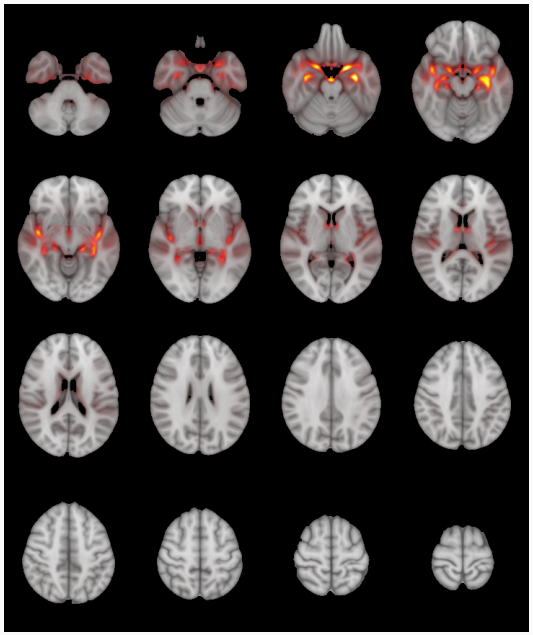
Explainable dementia classification: Validation

LRP

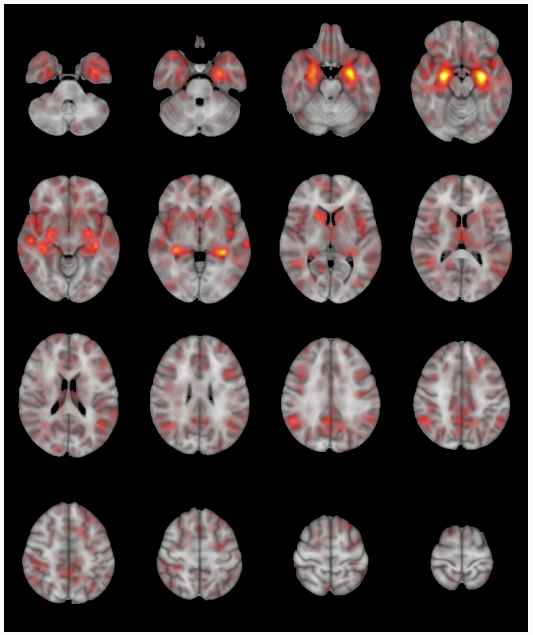


Explainable dementia classification: Validation

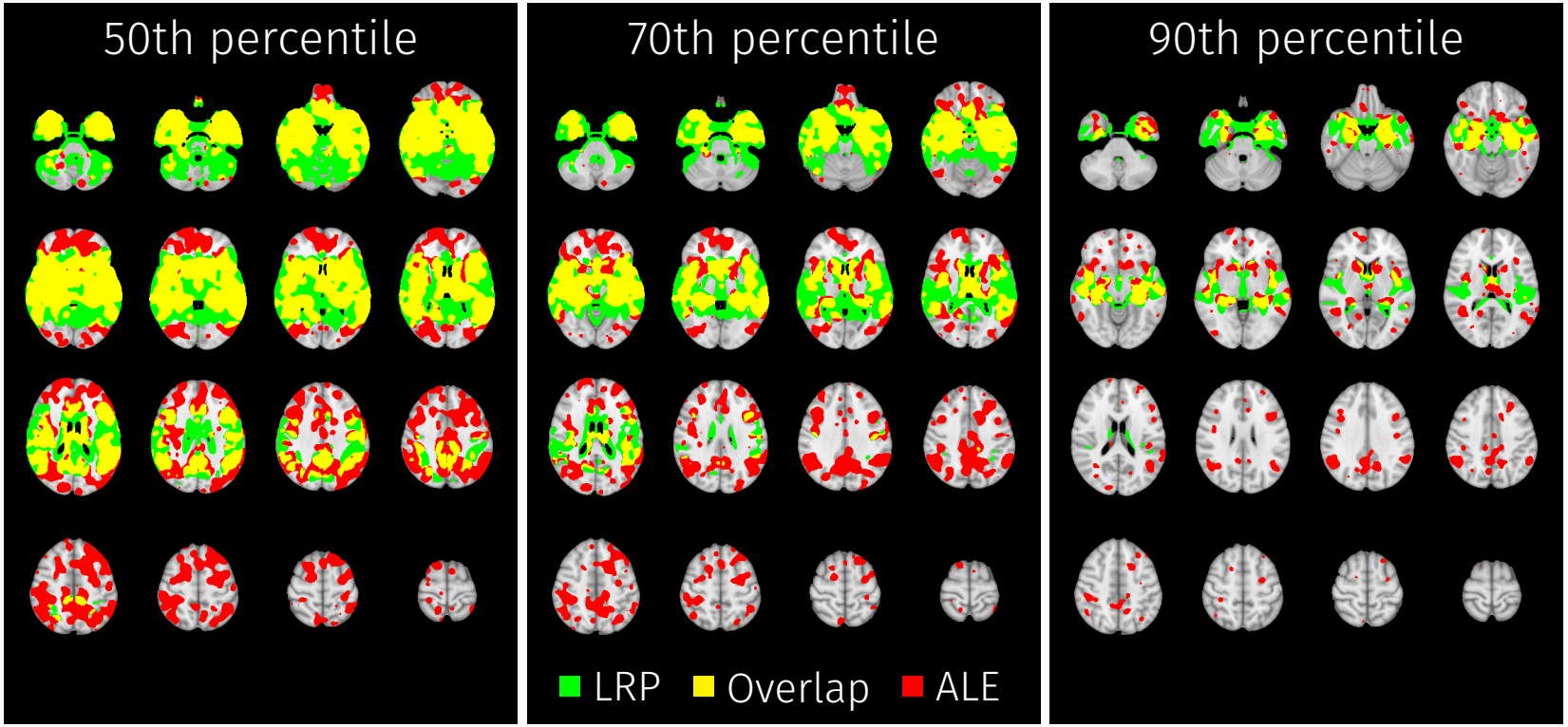
LRP



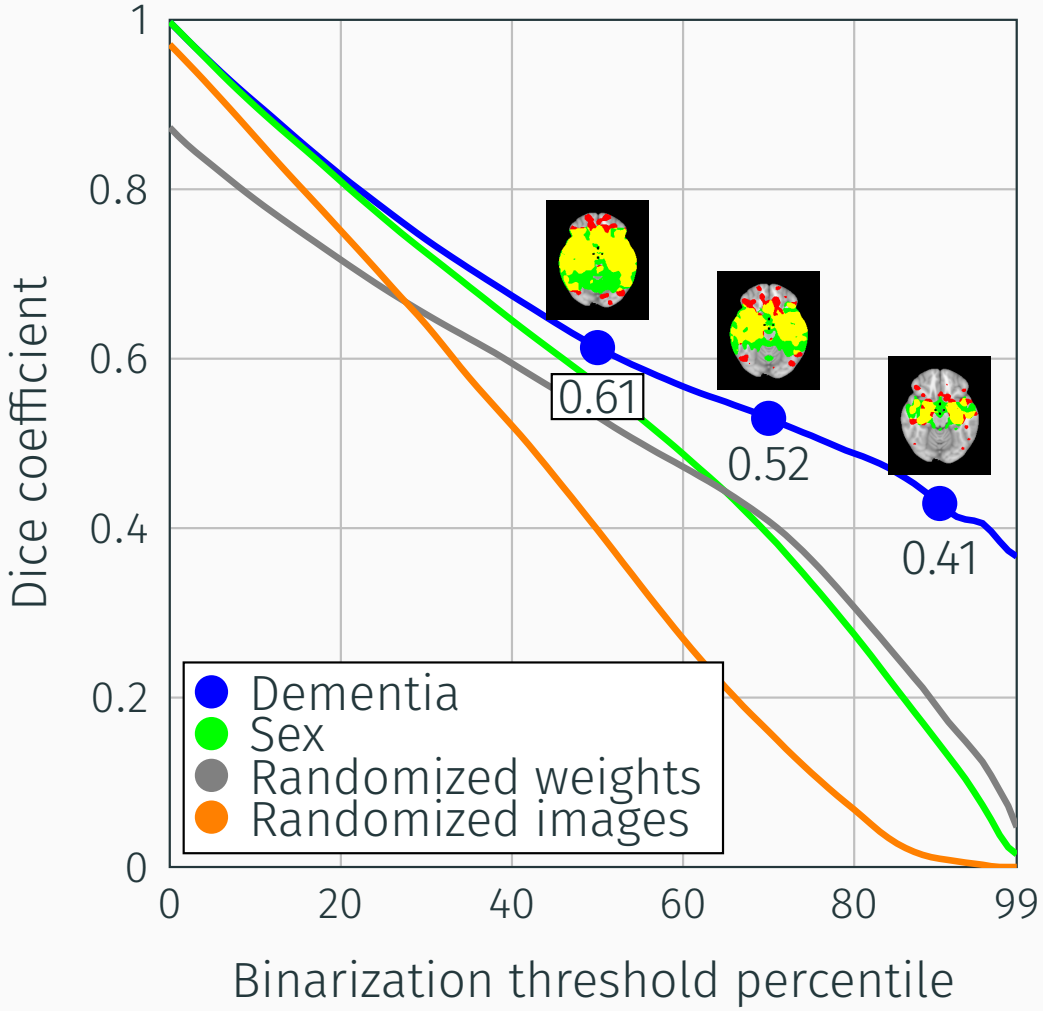
GingerALE



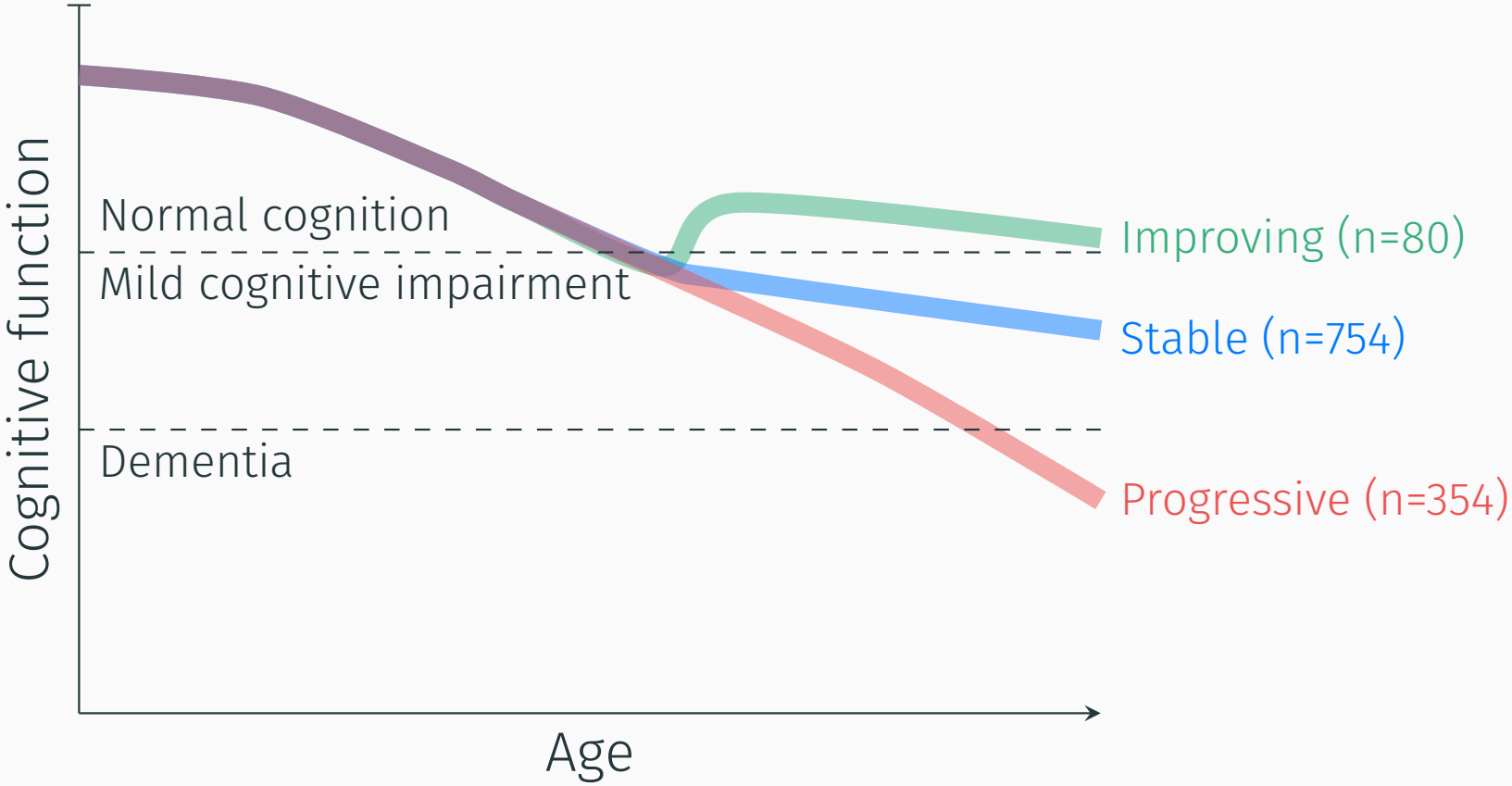
Explainable dementia classification: Validation



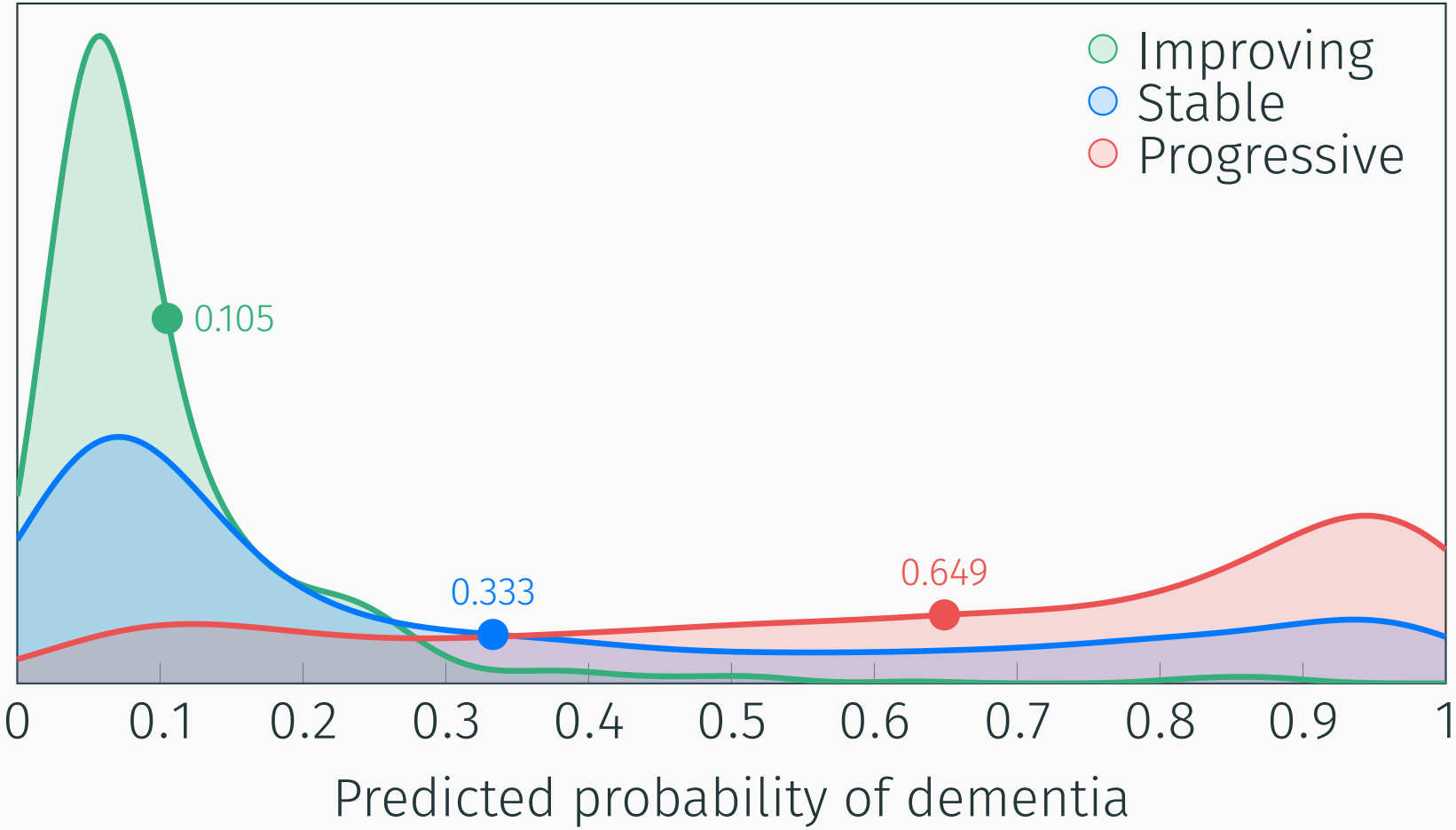
Explainable dementia classification: Validation



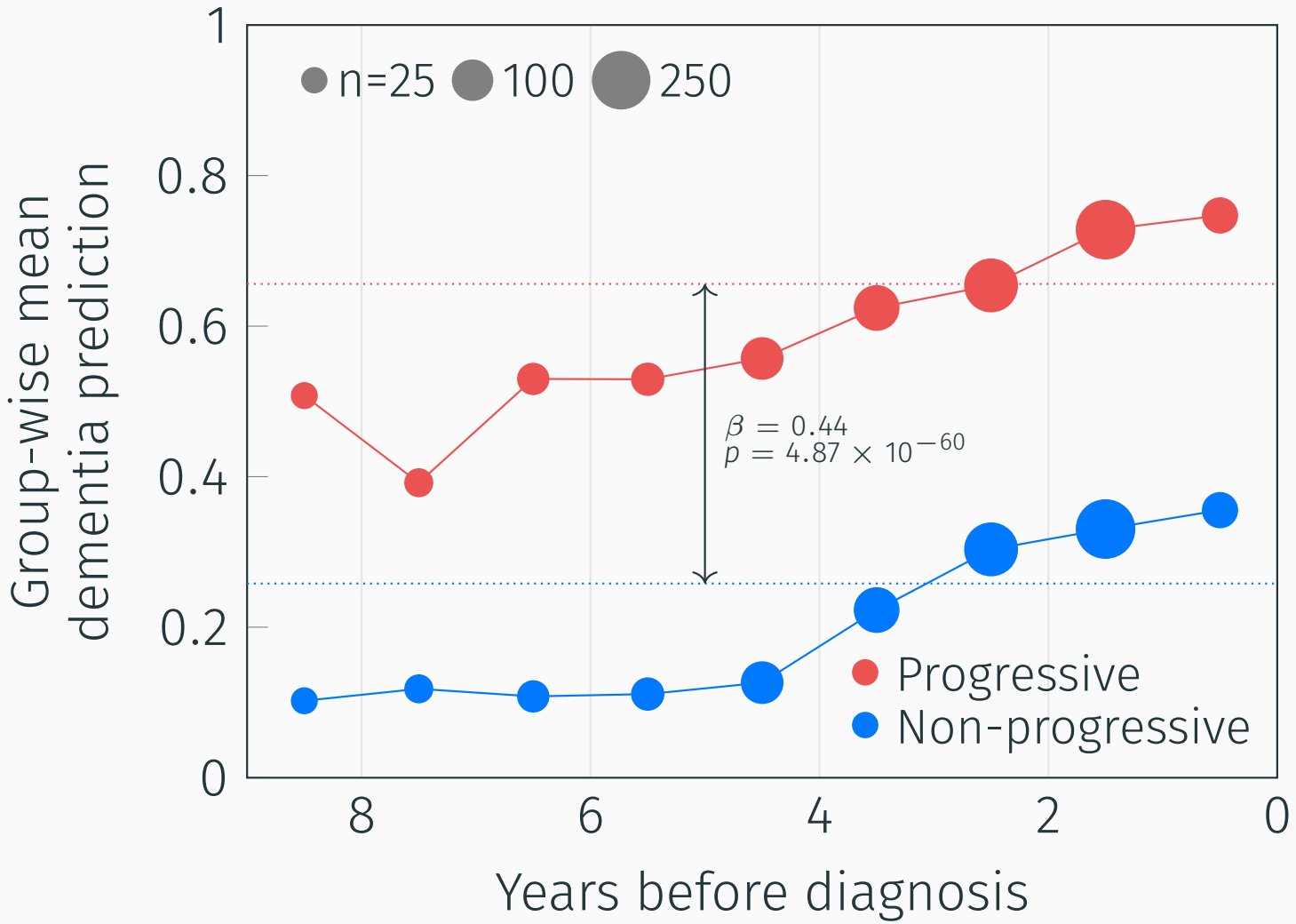
Explainable dementia classification: Application



Explainable dementia classification: Application

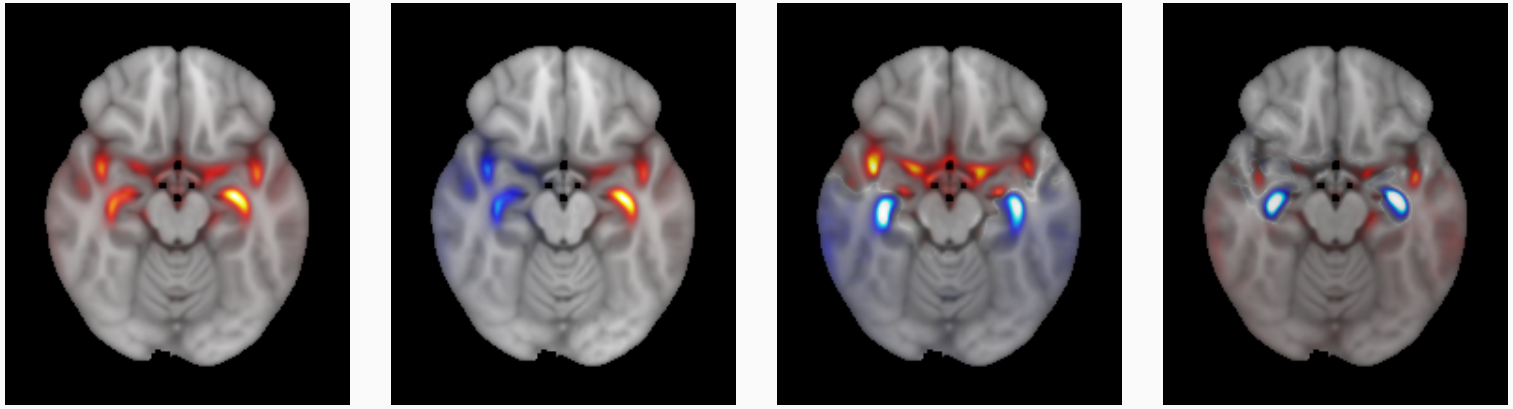


Explainable dementia classification: Application

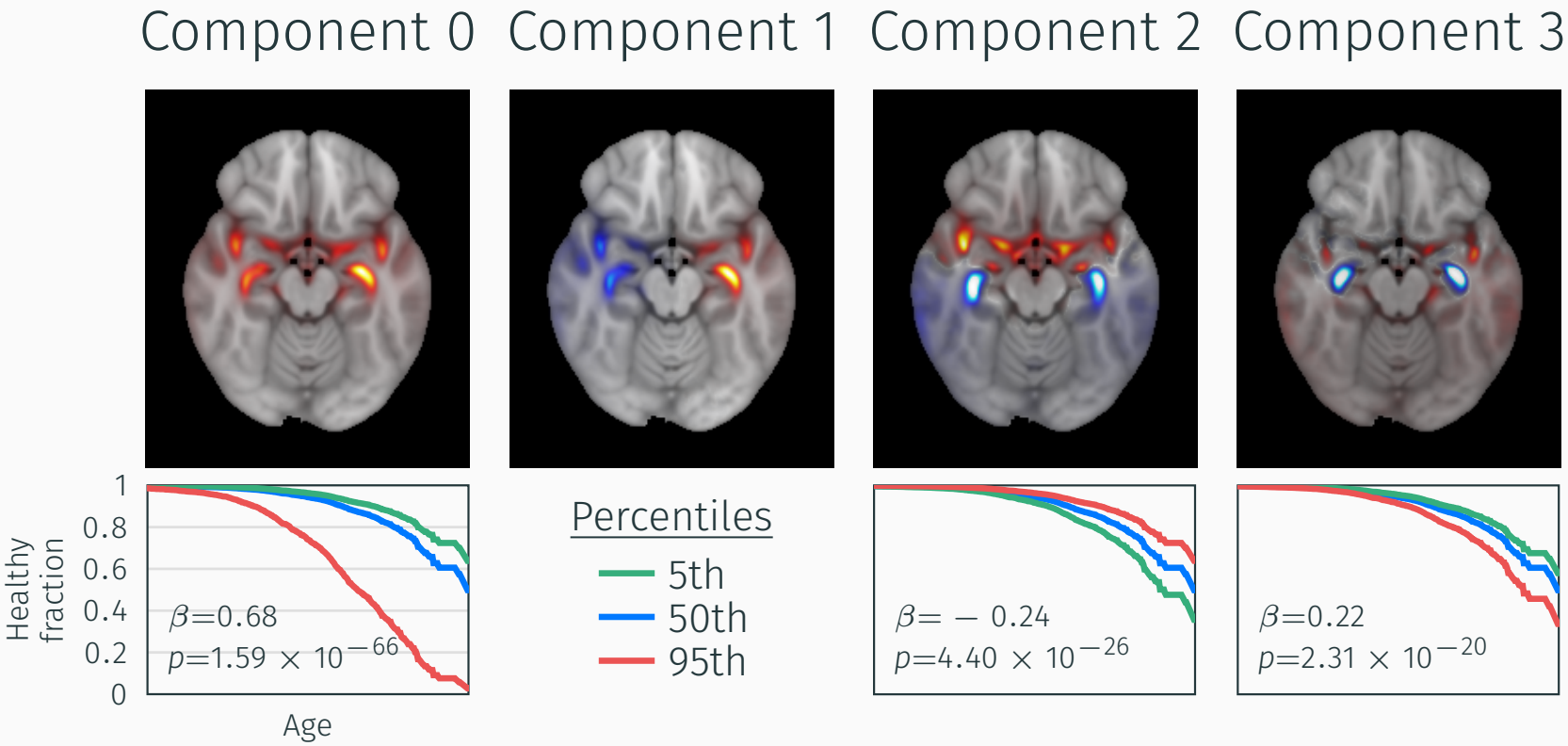


Explainable dementia classification: Application

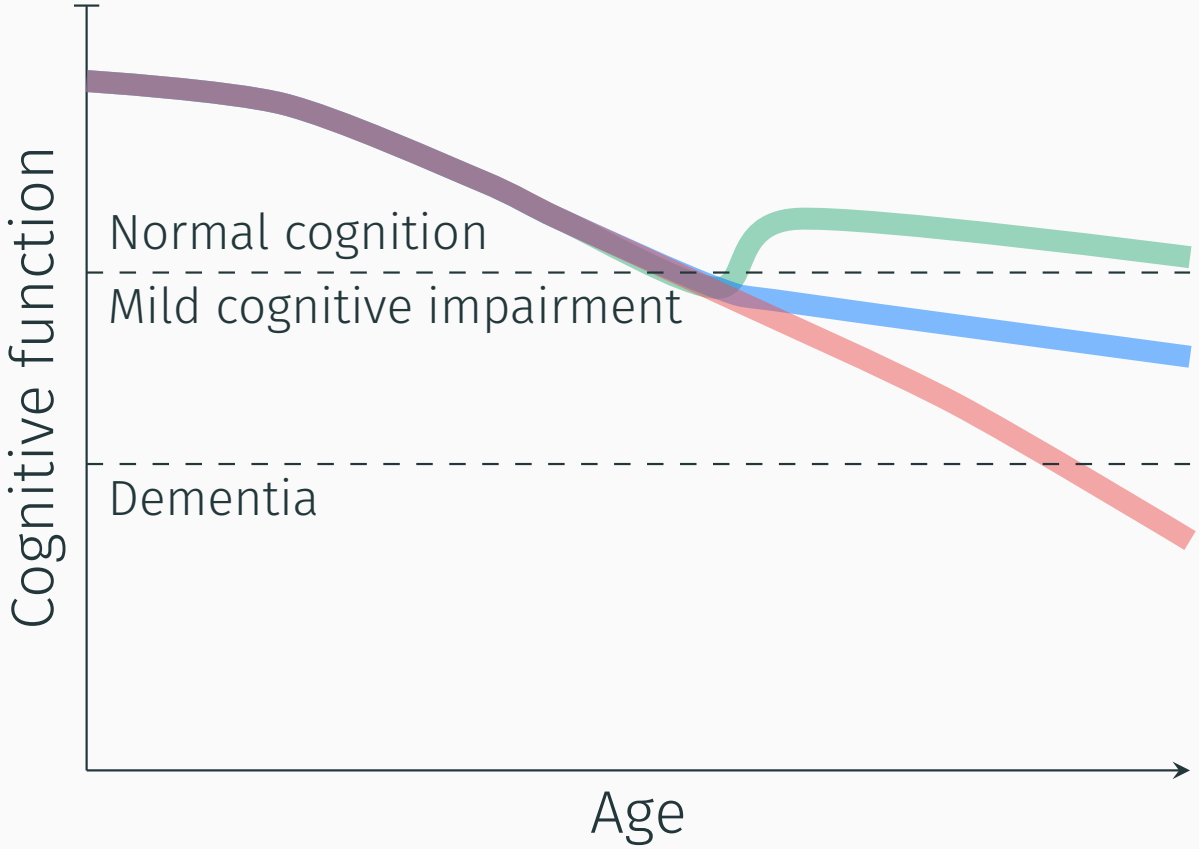
Component 0 Component 1 Component 2 Component 3



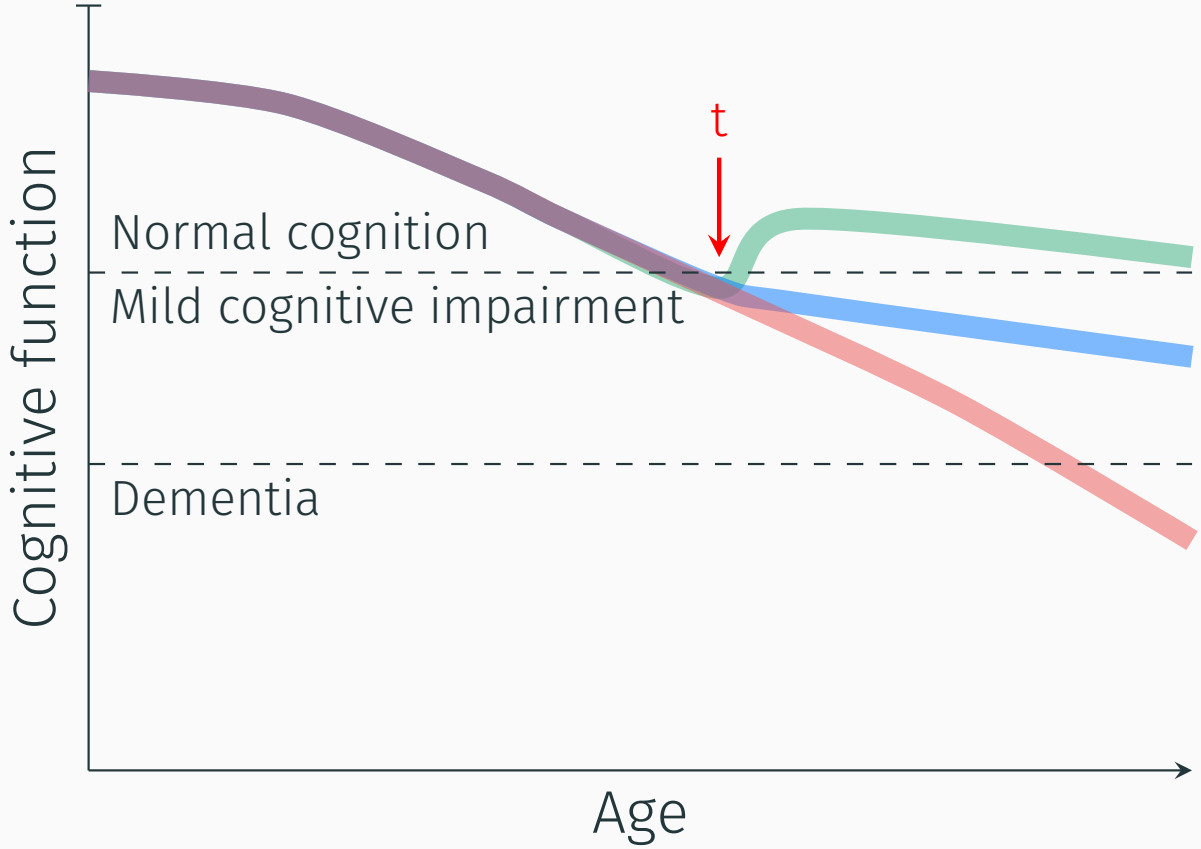
Explainable dementia classification: Application



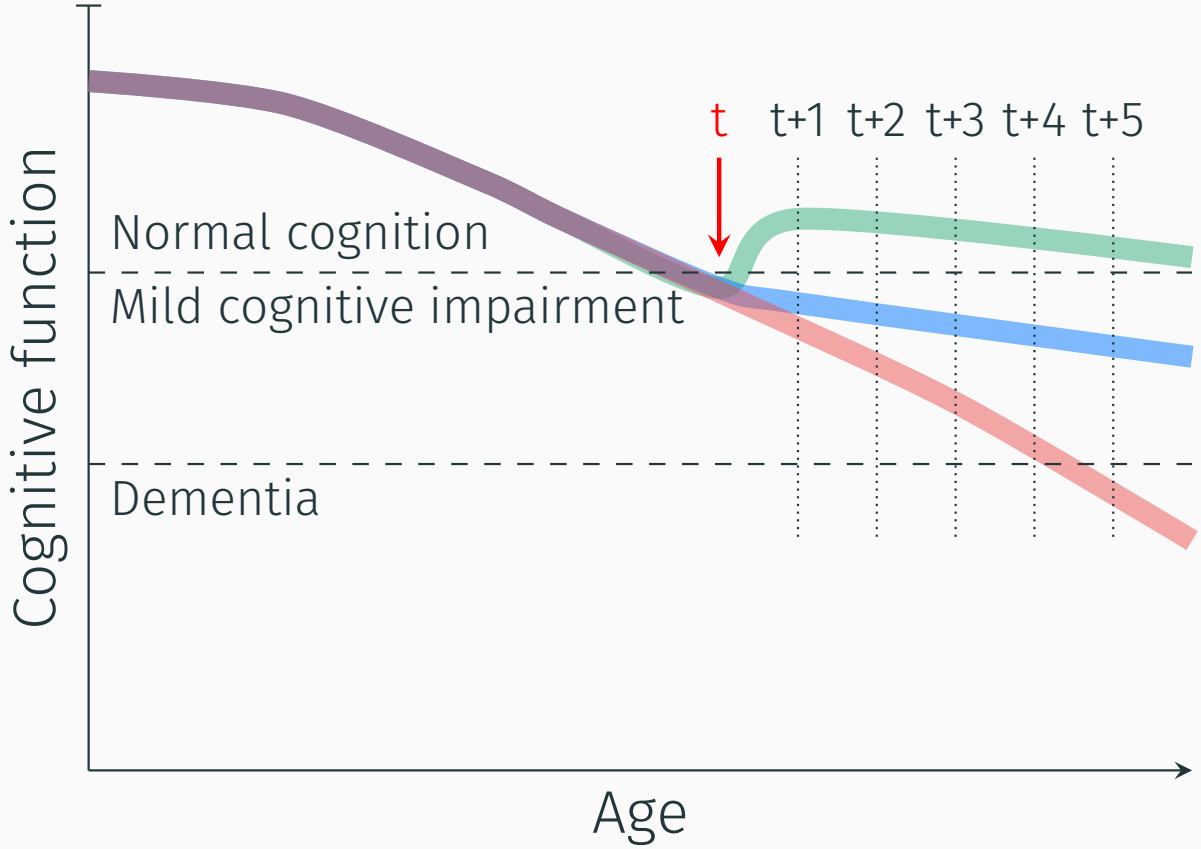
Explainable dementia classification: Application



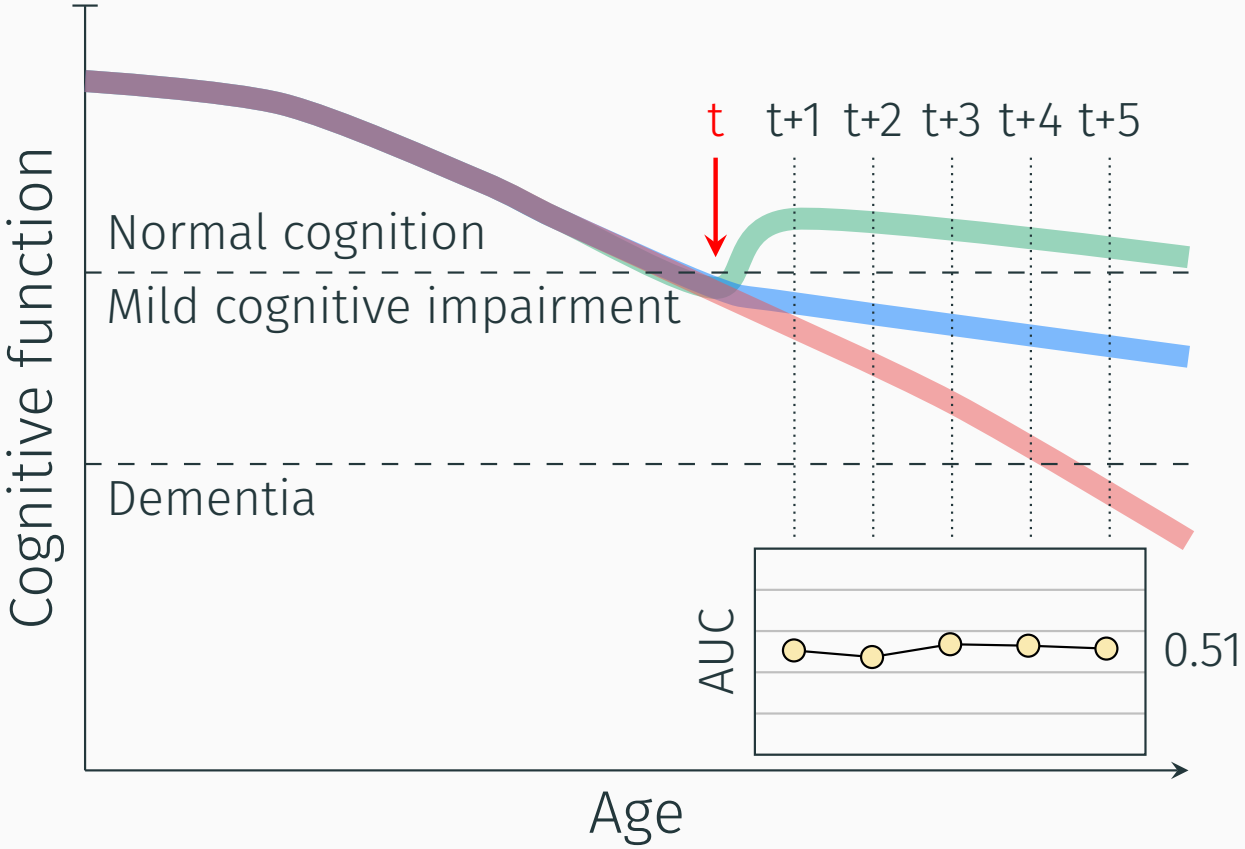
Explainable dementia classification: Application



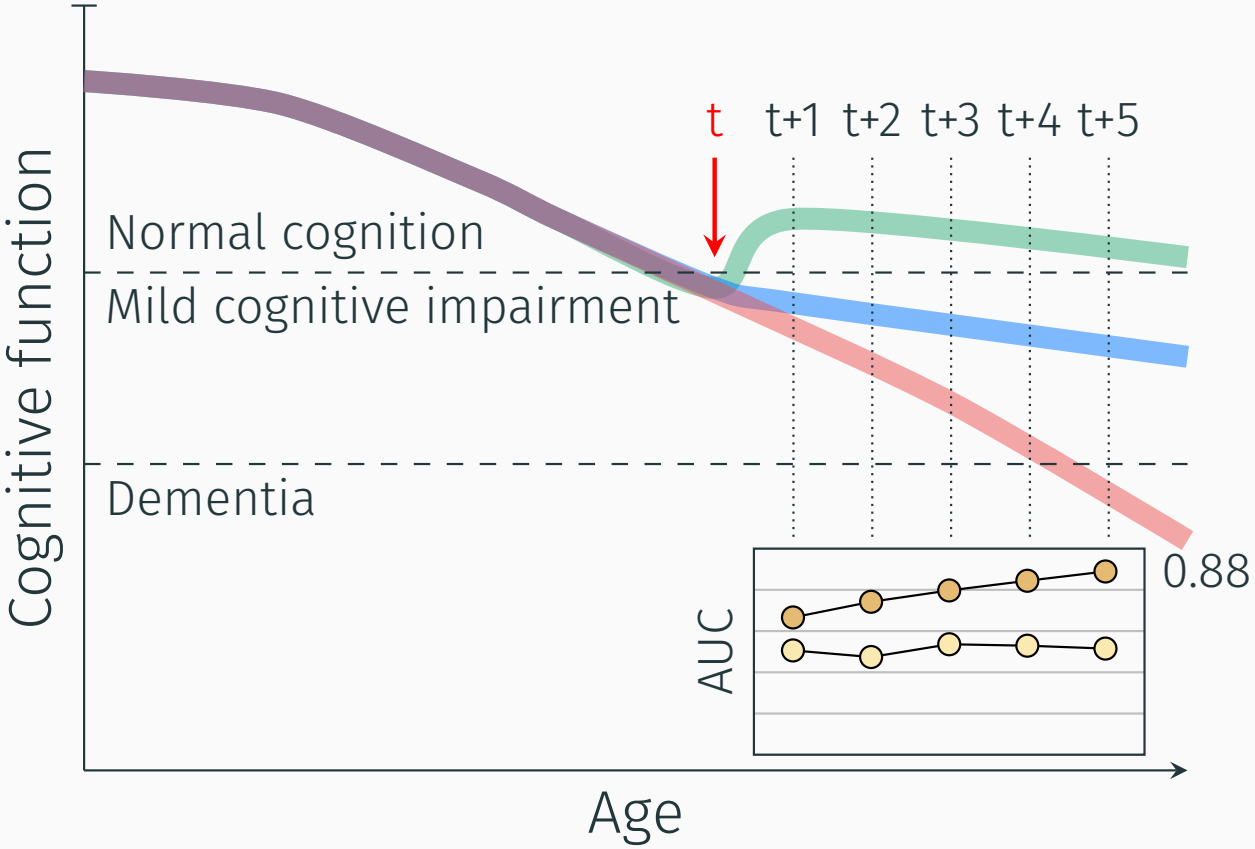
Explainable dementia classification: Application



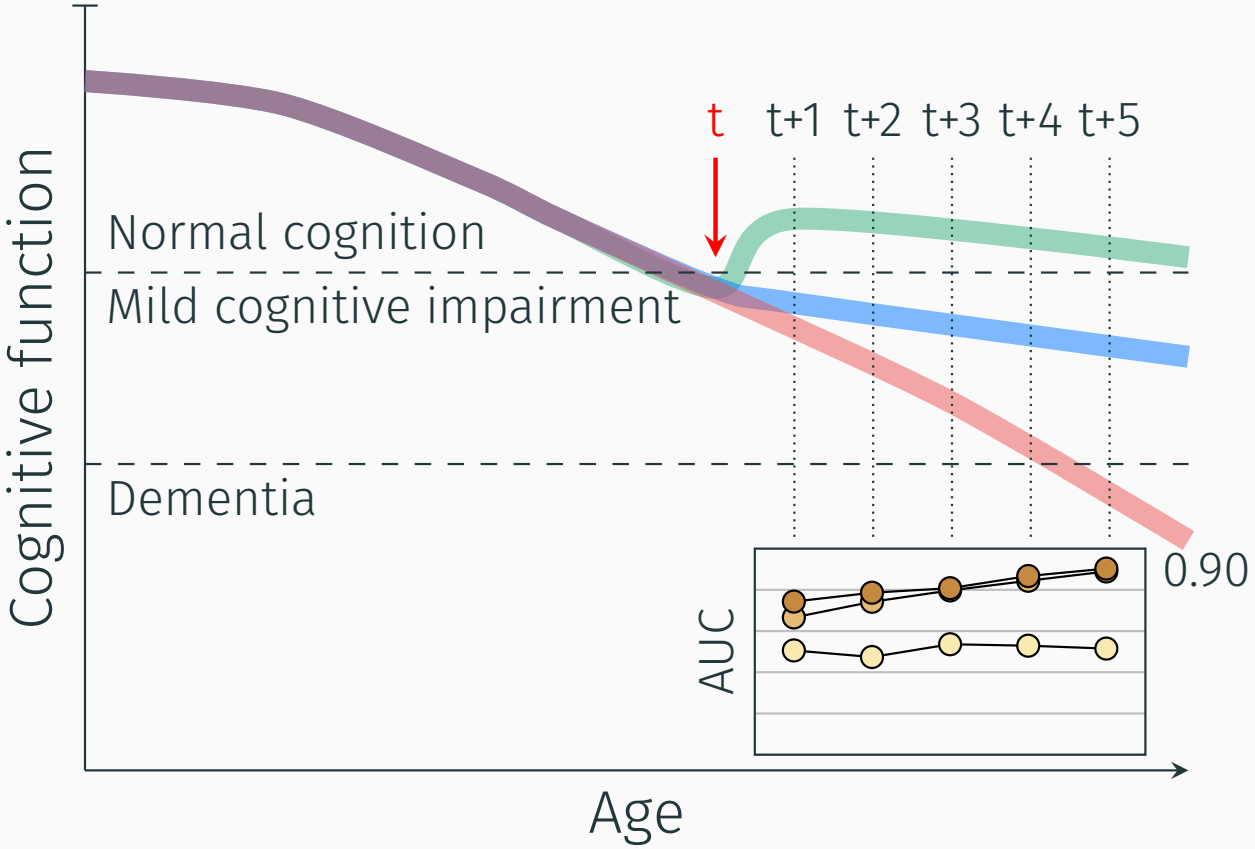
Explainable dementia classification: Application



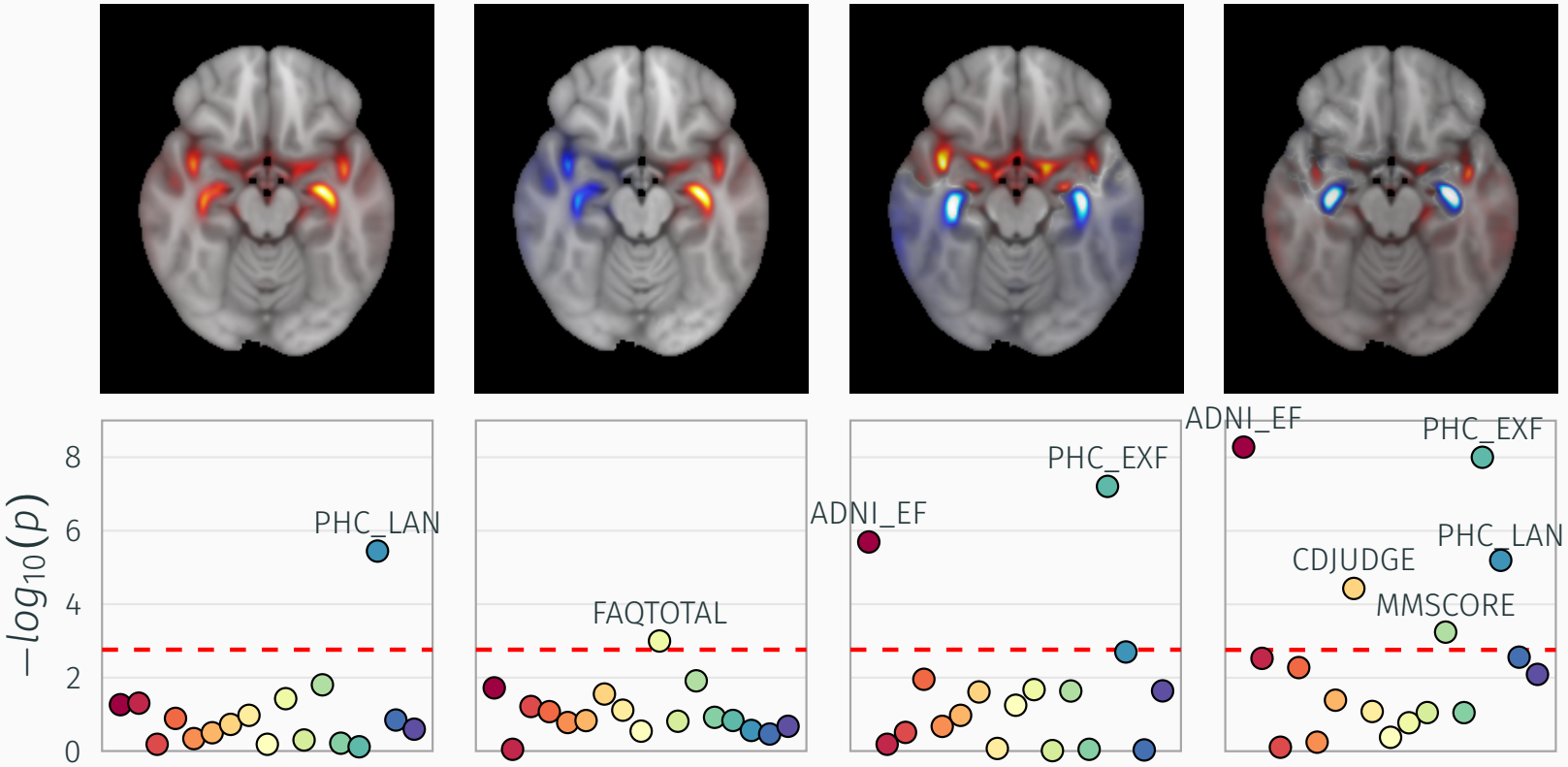
Explainable dementia classification: Application



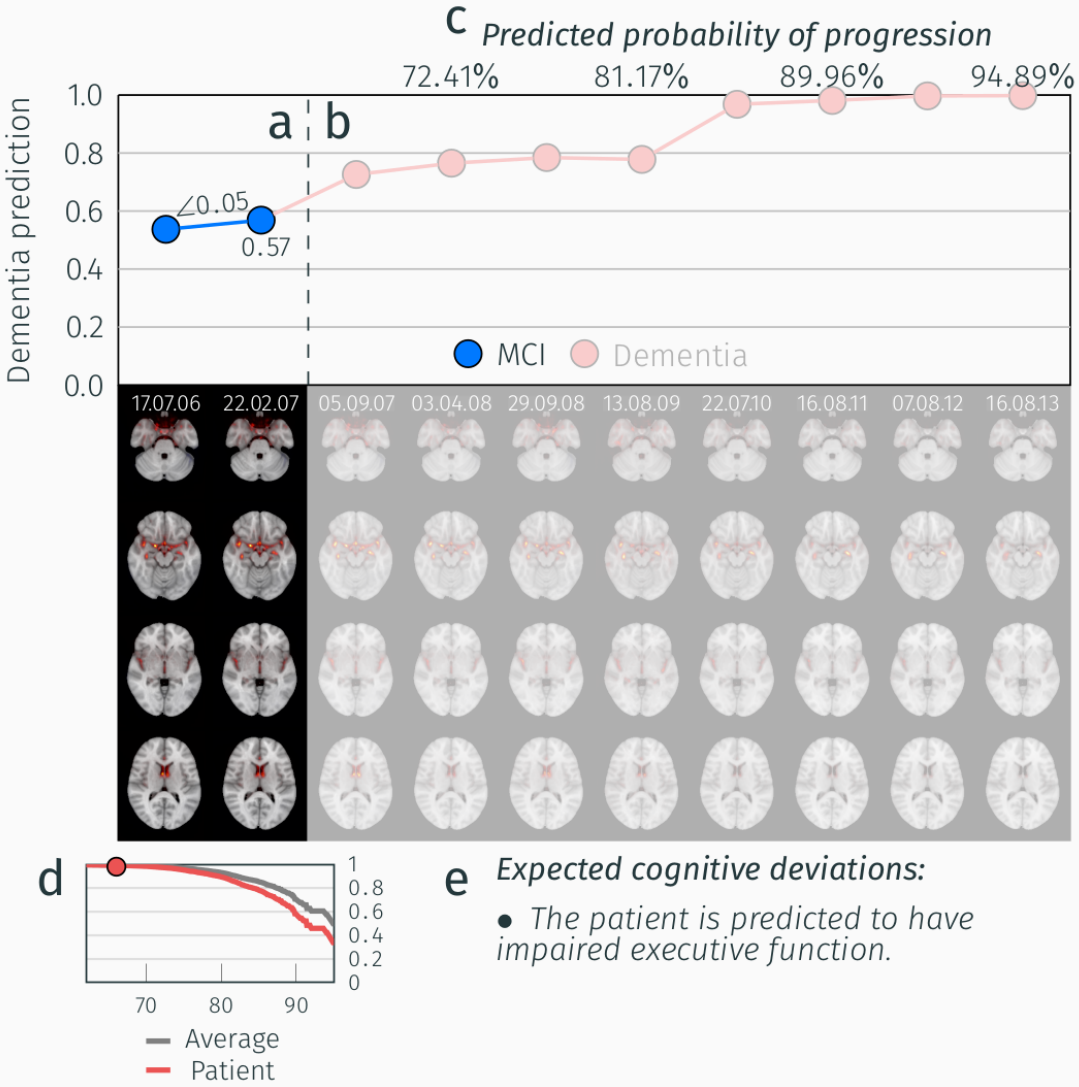
Explainable dementia classification: Application



Explainable dementia classification: Application



Explainable dementia classification: Application



Explainable brain age

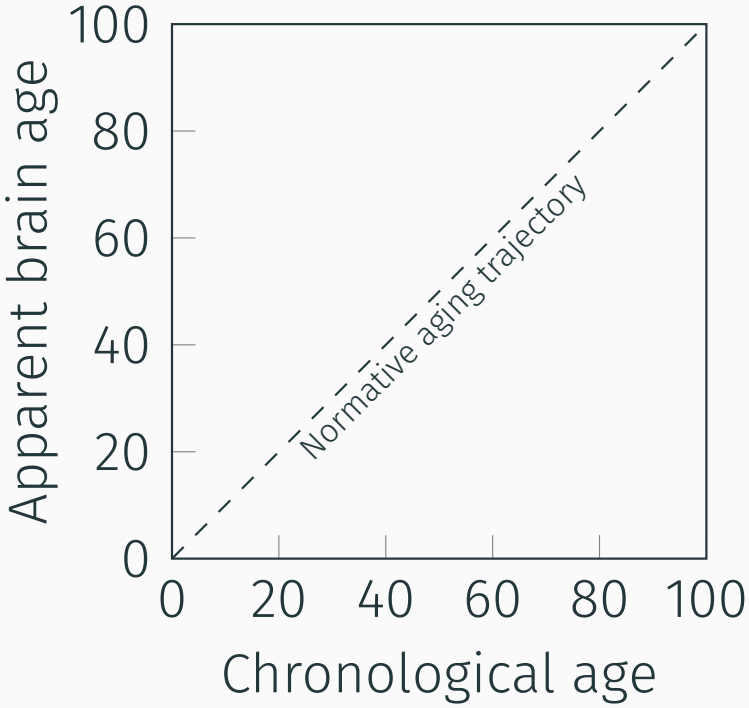
UNIVERSITY
OF OSLO

Explainable brain age: Motivation

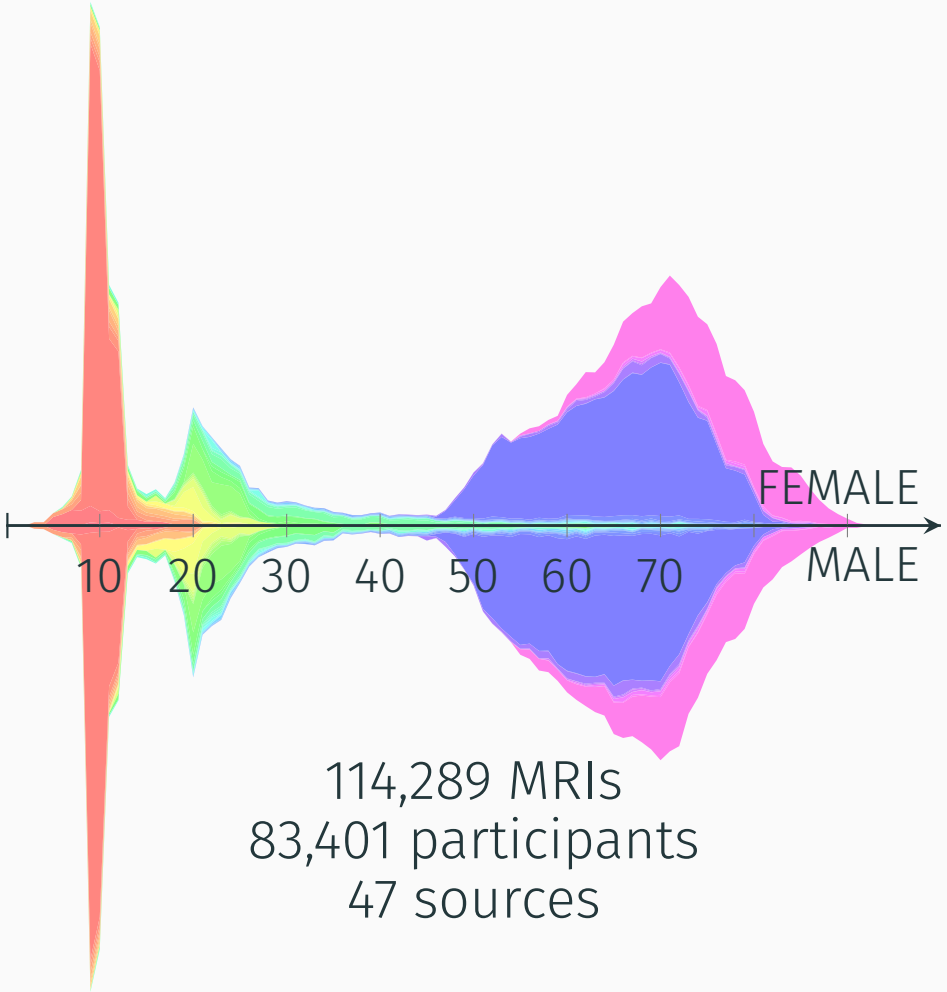
Generated by Dall-E 3

Explainable brain age: Motivation

Generated by Dall-E 3

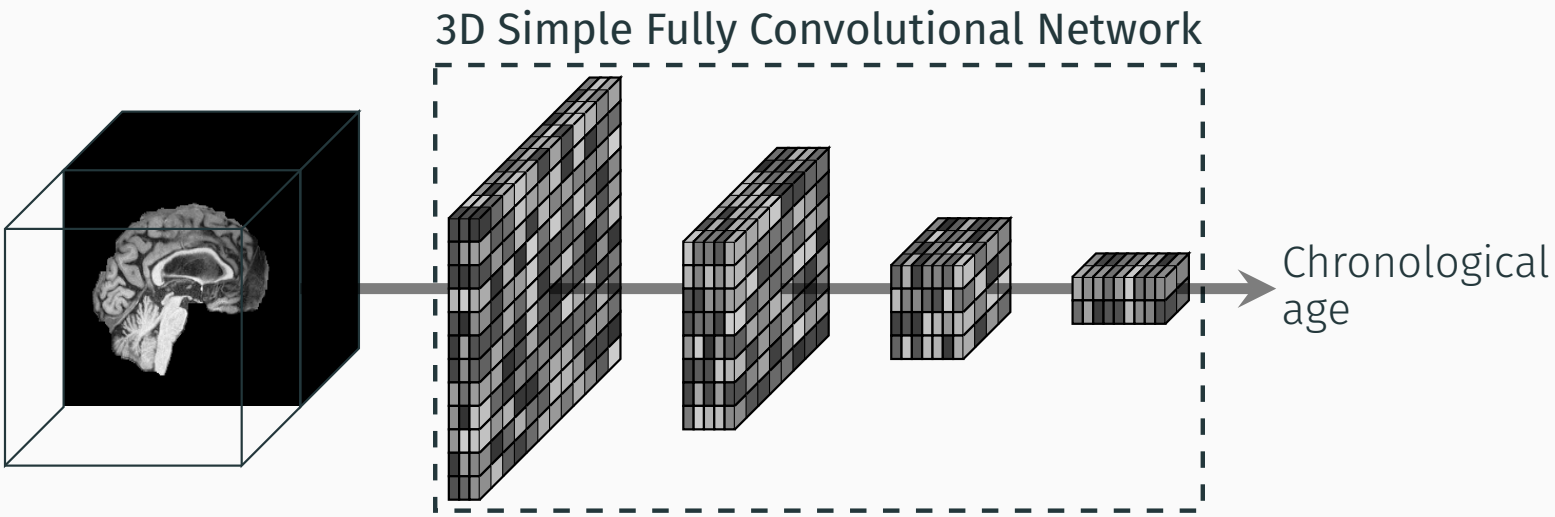


Explainable brain age: Motivation

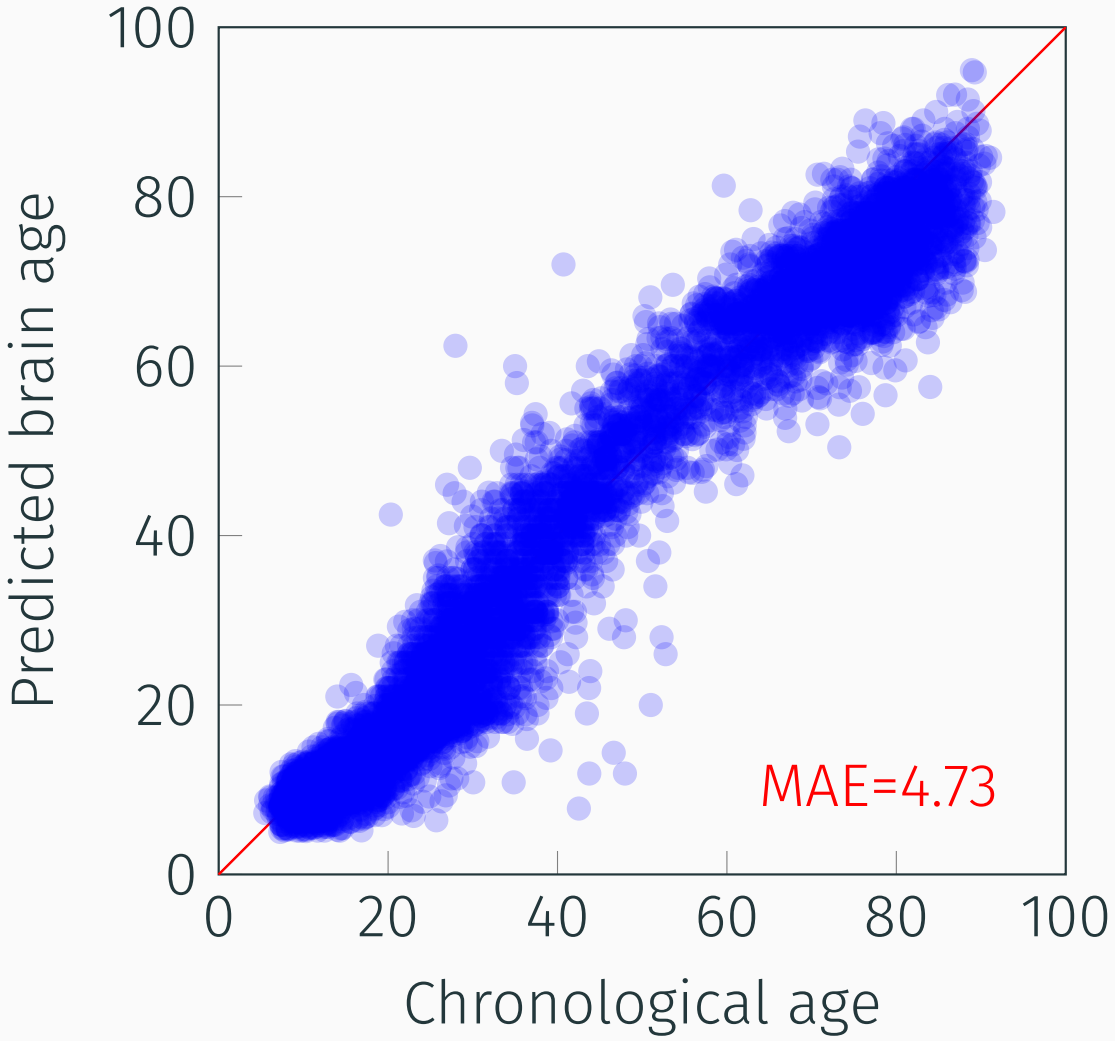


- ds002424
- HBN
- ABCD
- QTAB
- PING
- ADHD200
- PNC
- ABIDE-II
- ds000119
- ABIDE-I
- BRAINMINT
- SLIM
- QTIM
- Beijing
- AOMIC-PIOP2
- ds000202
- AOMIC-PIOP1
- AOMIC-ID1000
- CoRR
- HCP
- FCON1000
- ds000171
- TOP
- SCZ-Z
- NIMH
- NKI-RS
- MPI-LEMON
- ds003592
- ds004302
- ds000222
- SALD
- IXI
- DLBS
- Cam-CAN
- StrokeMRI
- PPMI
- UKBB
- Tao-Wu
- ds000245
- OASIS3
- Demgen
- NEUROCON
- MIRIAD
- ds004392
- AIBL
- ANM
- ADNI

Explainable brain age: Motivation

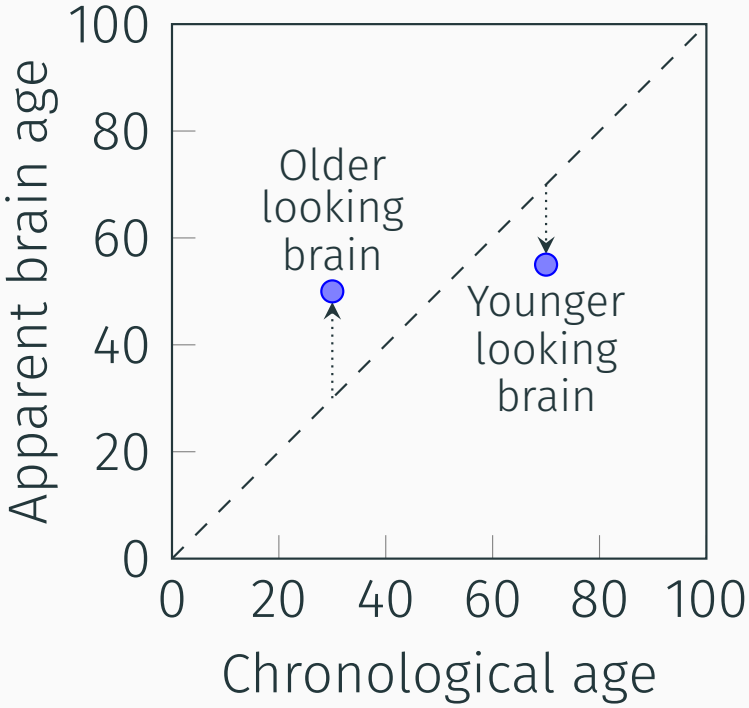


Explainable brain age: Motivation

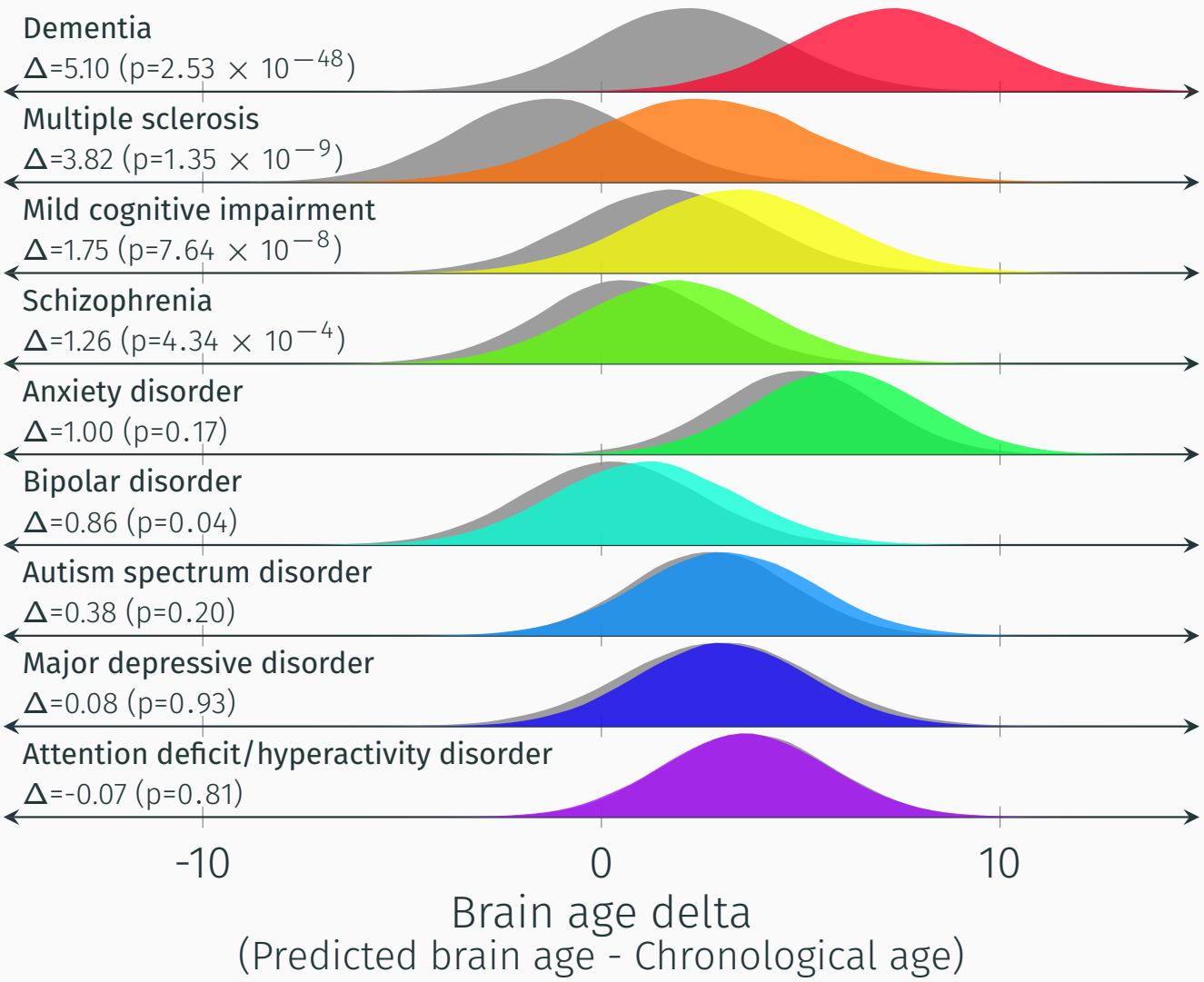


Explainable brain age: Motivation

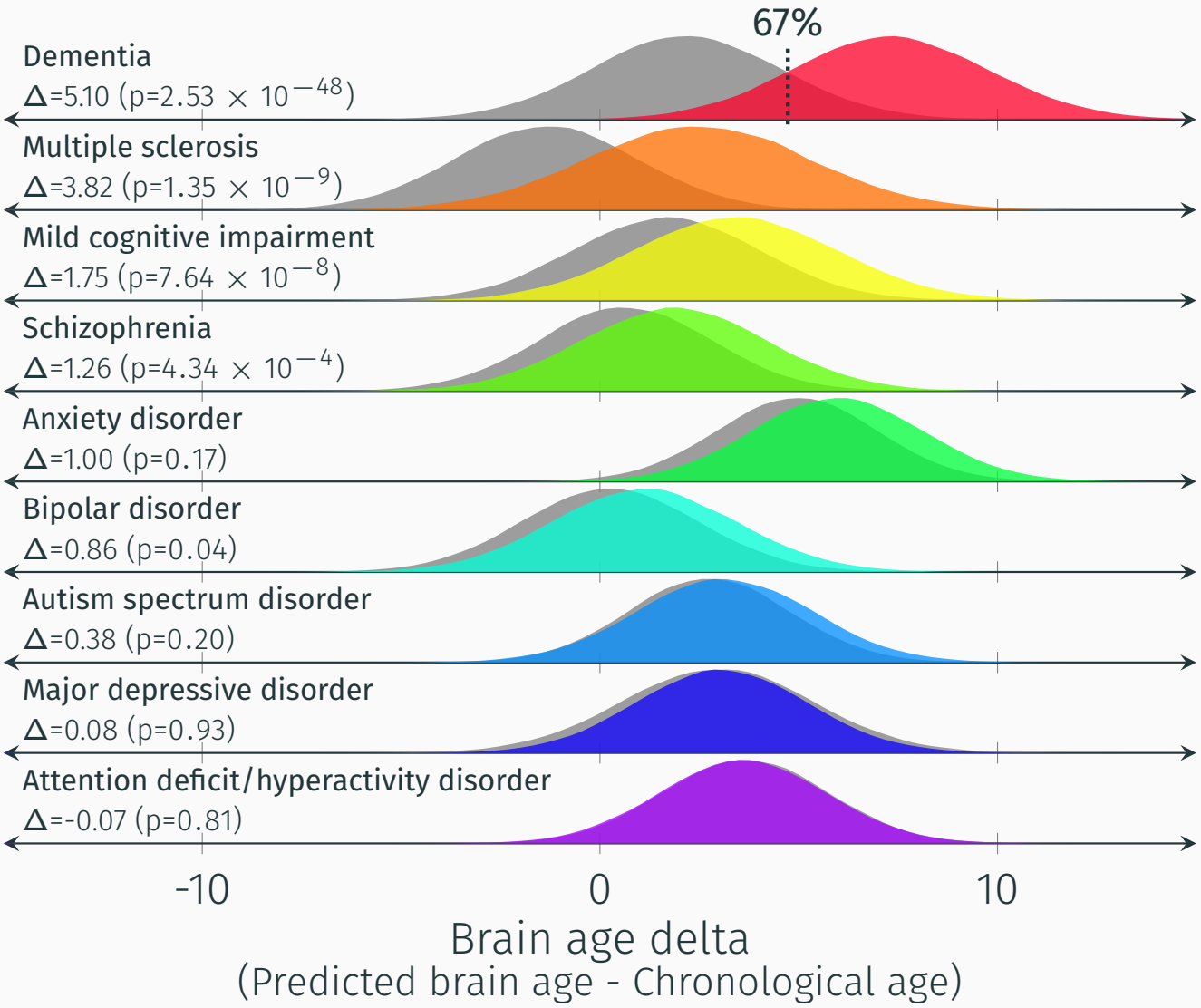
Generated by Dall-E 3



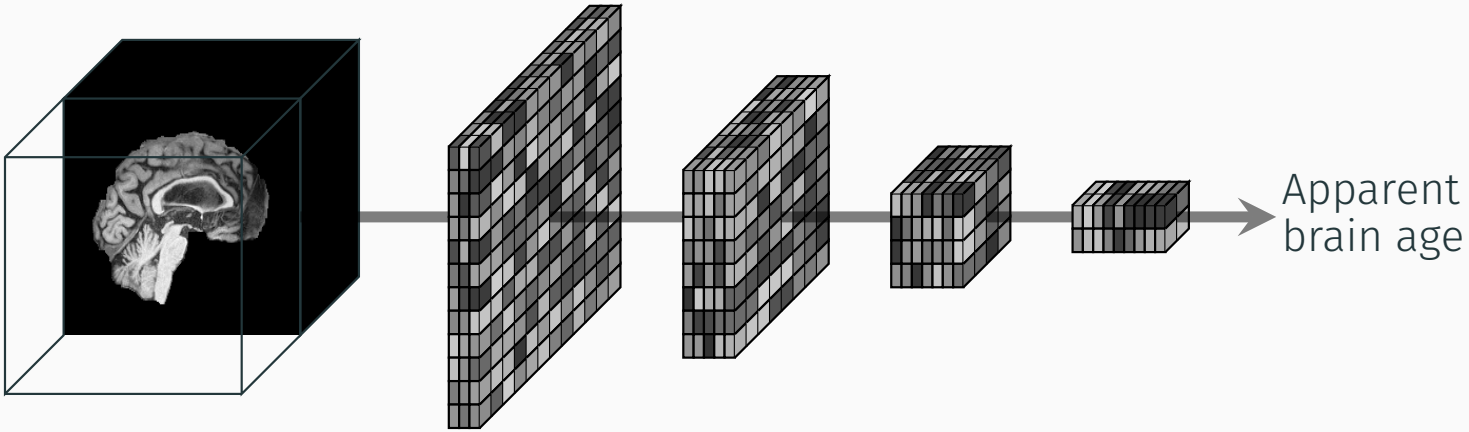
Explainable brain age: Motivation



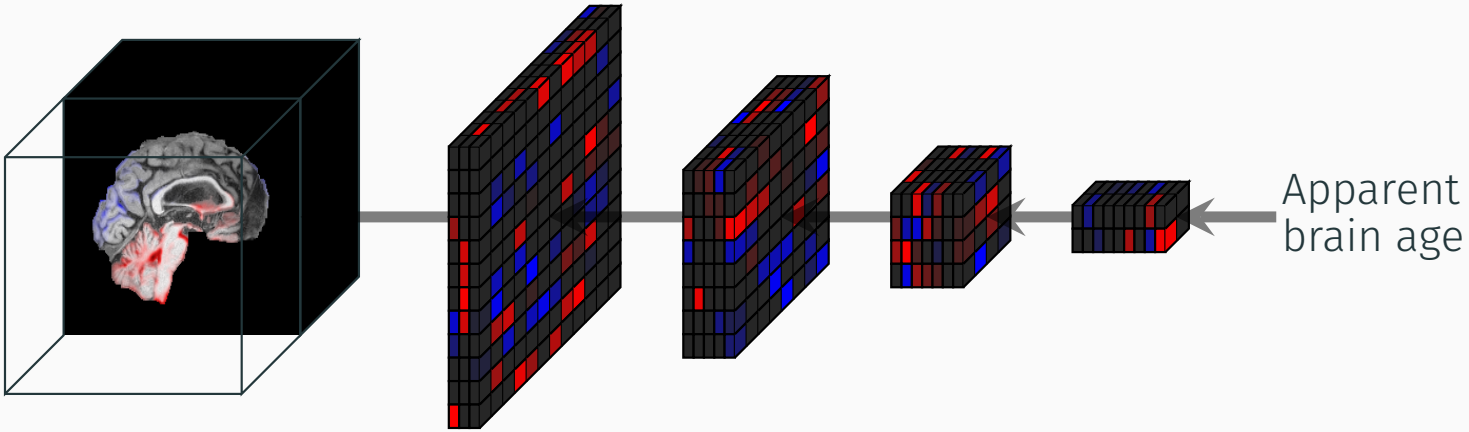
Explainable brain age: Motivation



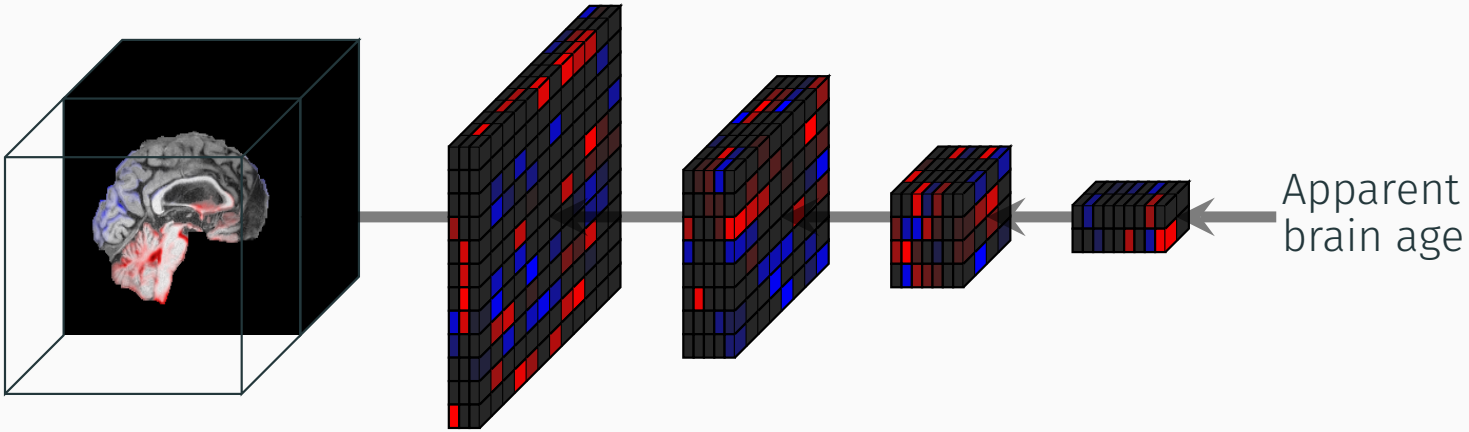
Explainable brain age: Methods



Explainable brain age: Methods



Explainable brain age: Methods

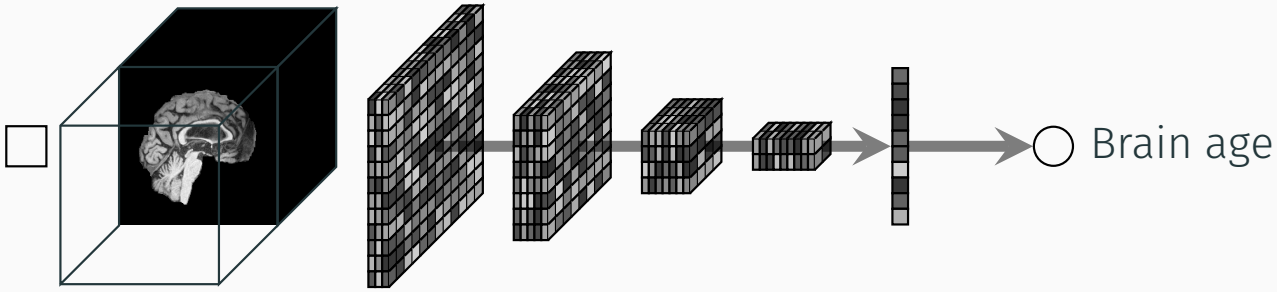


Filters

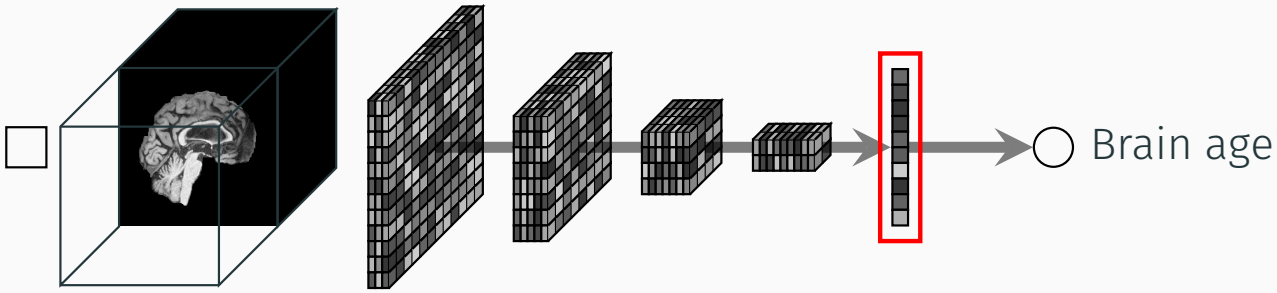
Explainable brain age: Methods

Feature correlation

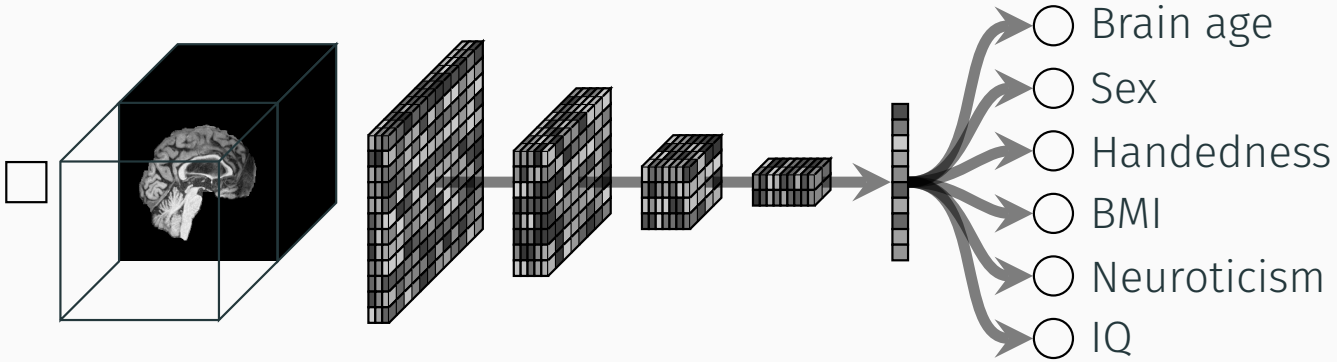
Explainable brain age: Methods



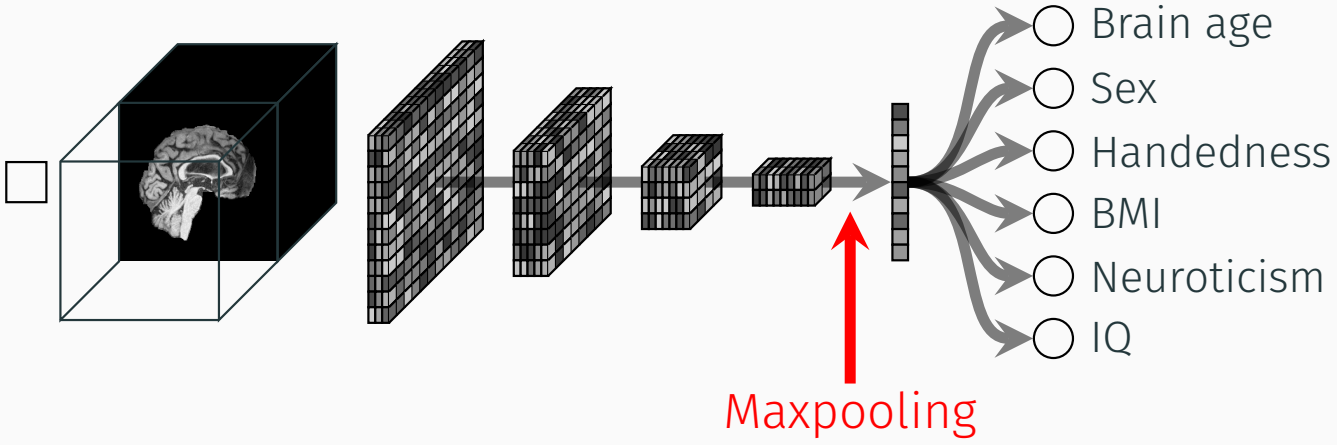
Explainable brain age: Methods



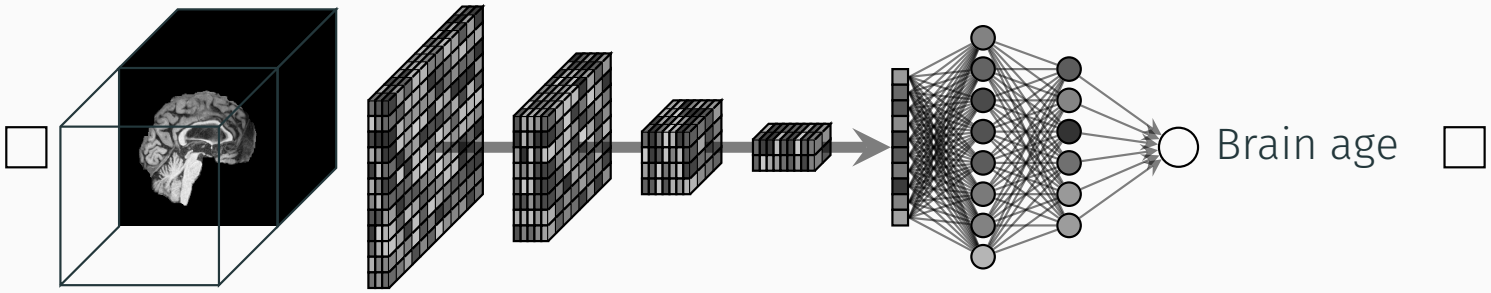
Explainable brain age: Methods



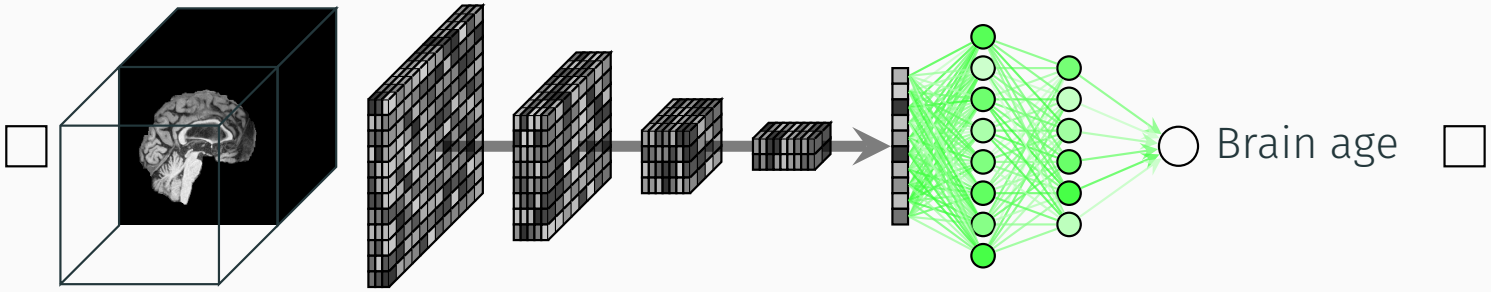
Explainable brain age: Methods



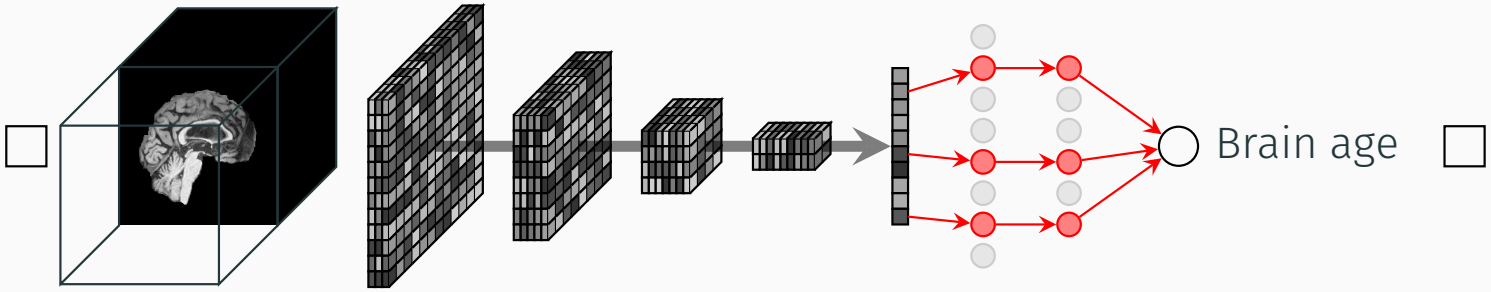
Explainable brain age: Methods



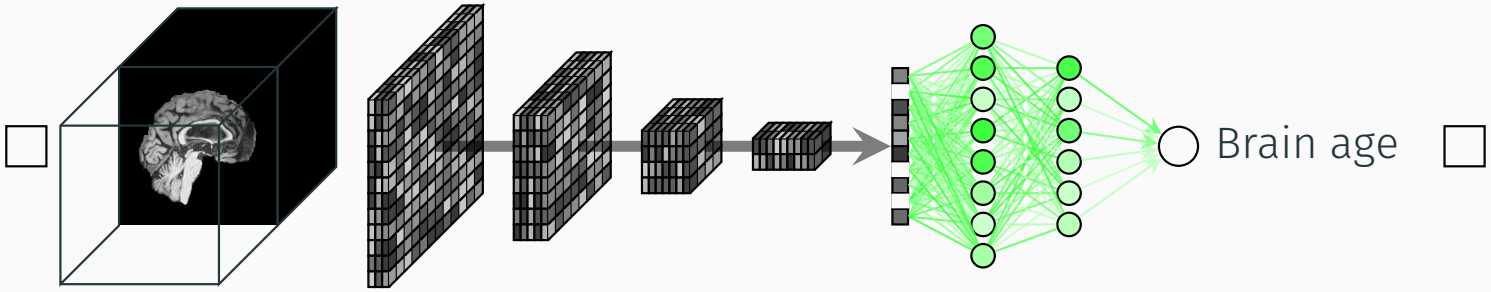
Explainable brain age: Methods



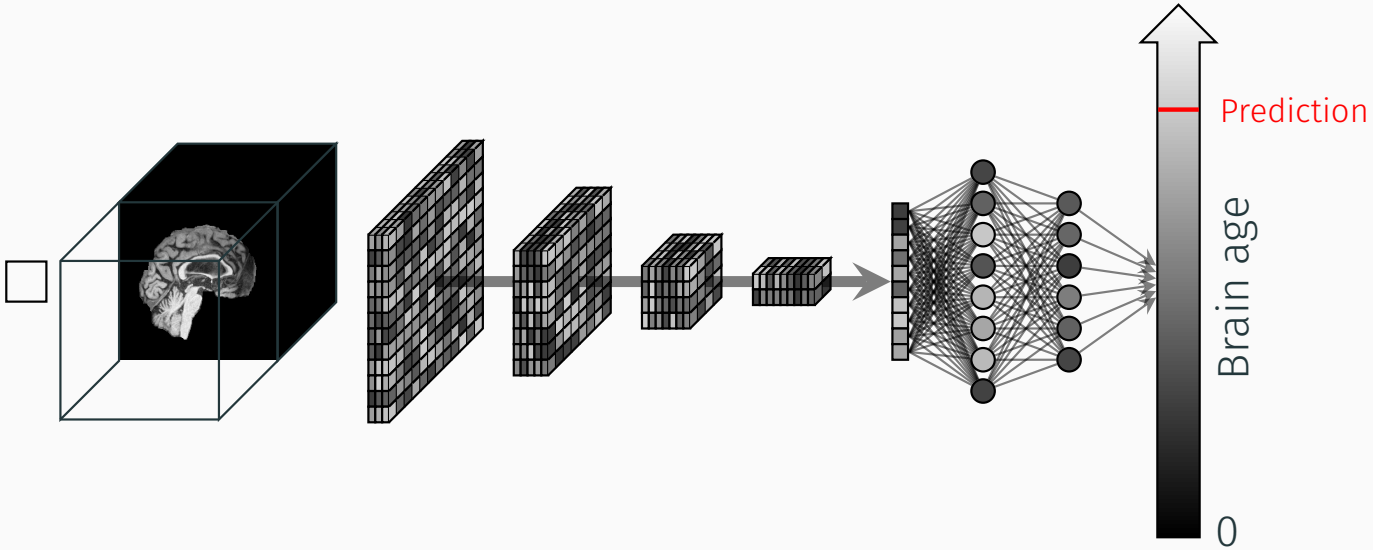
Explainable brain age: Methods



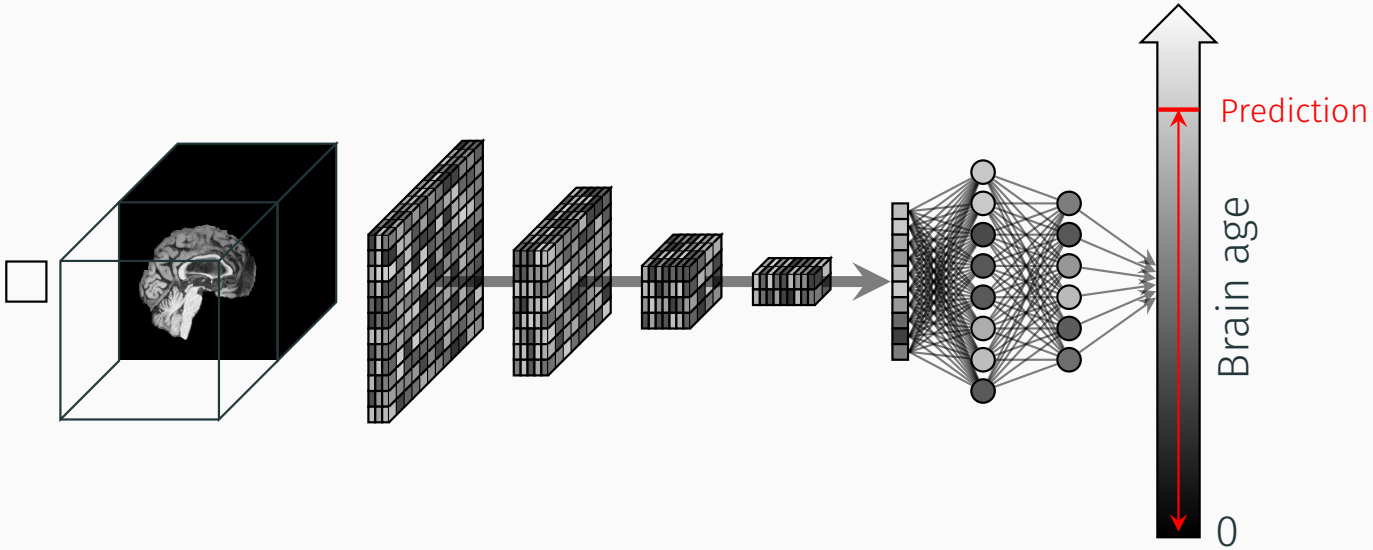
Explainable brain age: Methods



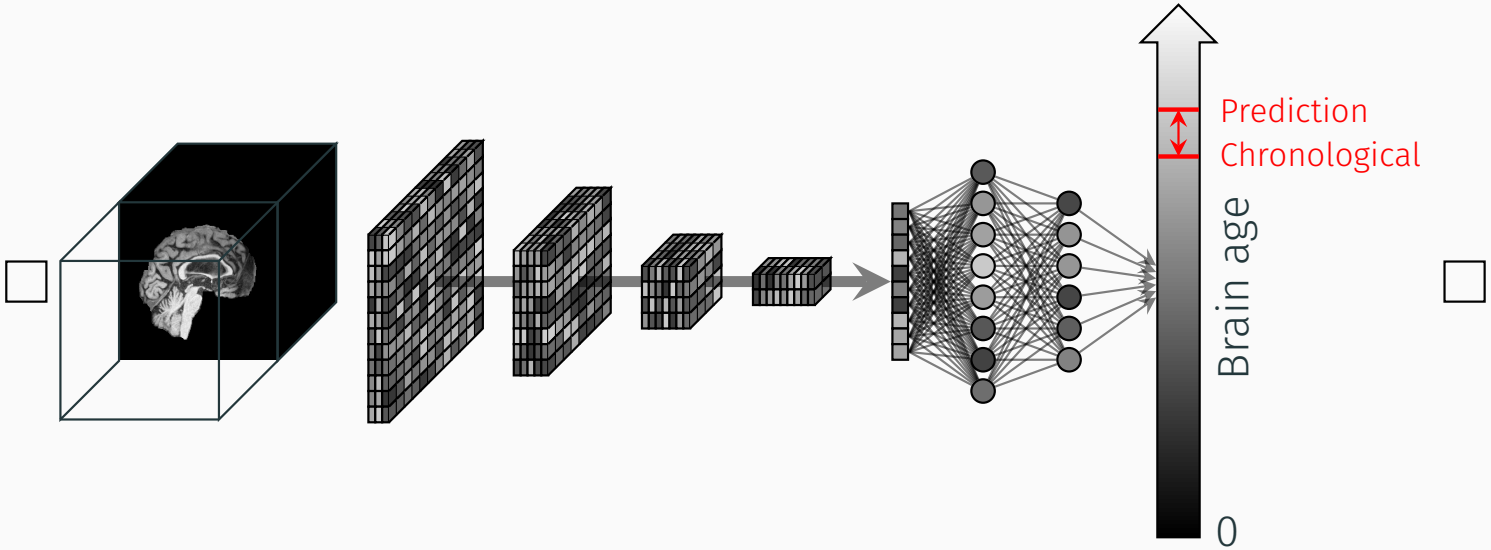
Explainable brain age: Methods



Explainable brain age: Methods



Explainable brain age: Methods



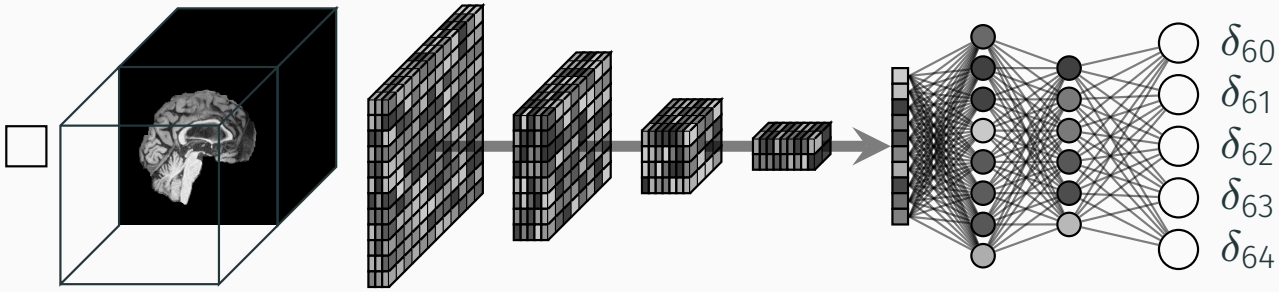
Explainable brain age: Methods

$$\frac{\text{Age}}{62}$$

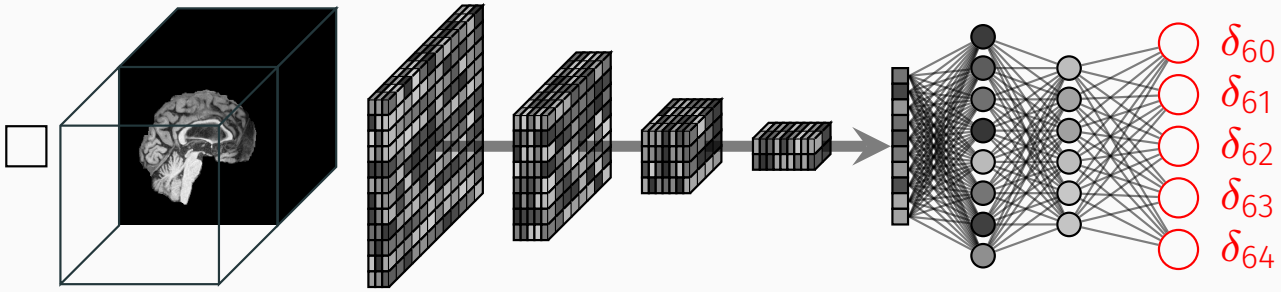
Explainable brain age: Methods

δ_{60}	δ_{61}	δ_{62}	δ_{63}	δ_{64}
2	1	0	-1	-2

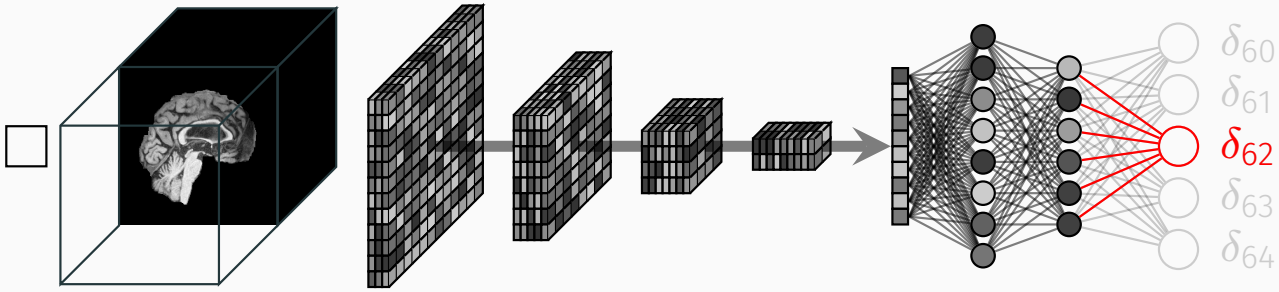
Explainable brain age: Methods



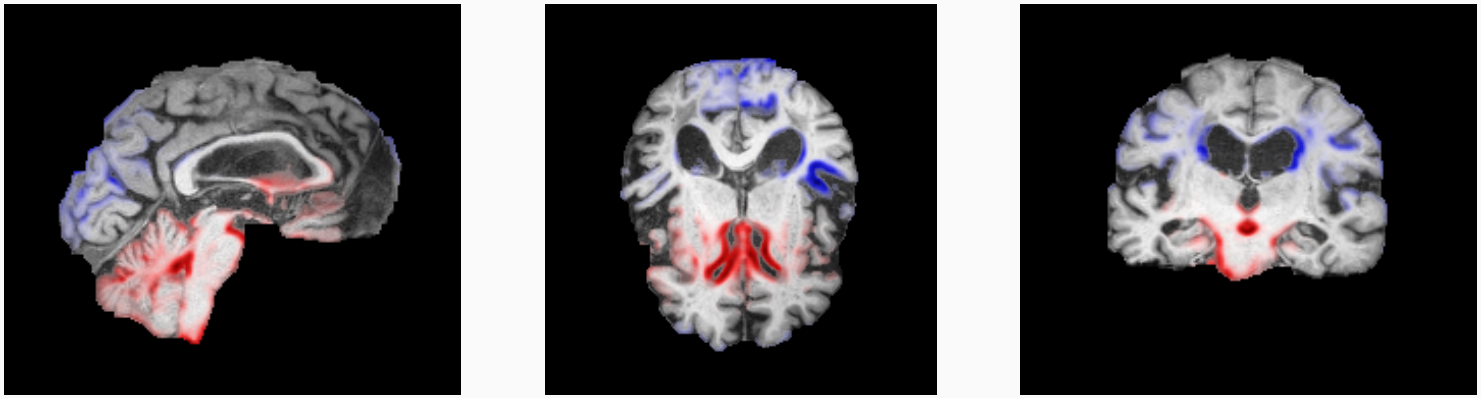
Explainable brain age: Methods



Explainable brain age: Methods



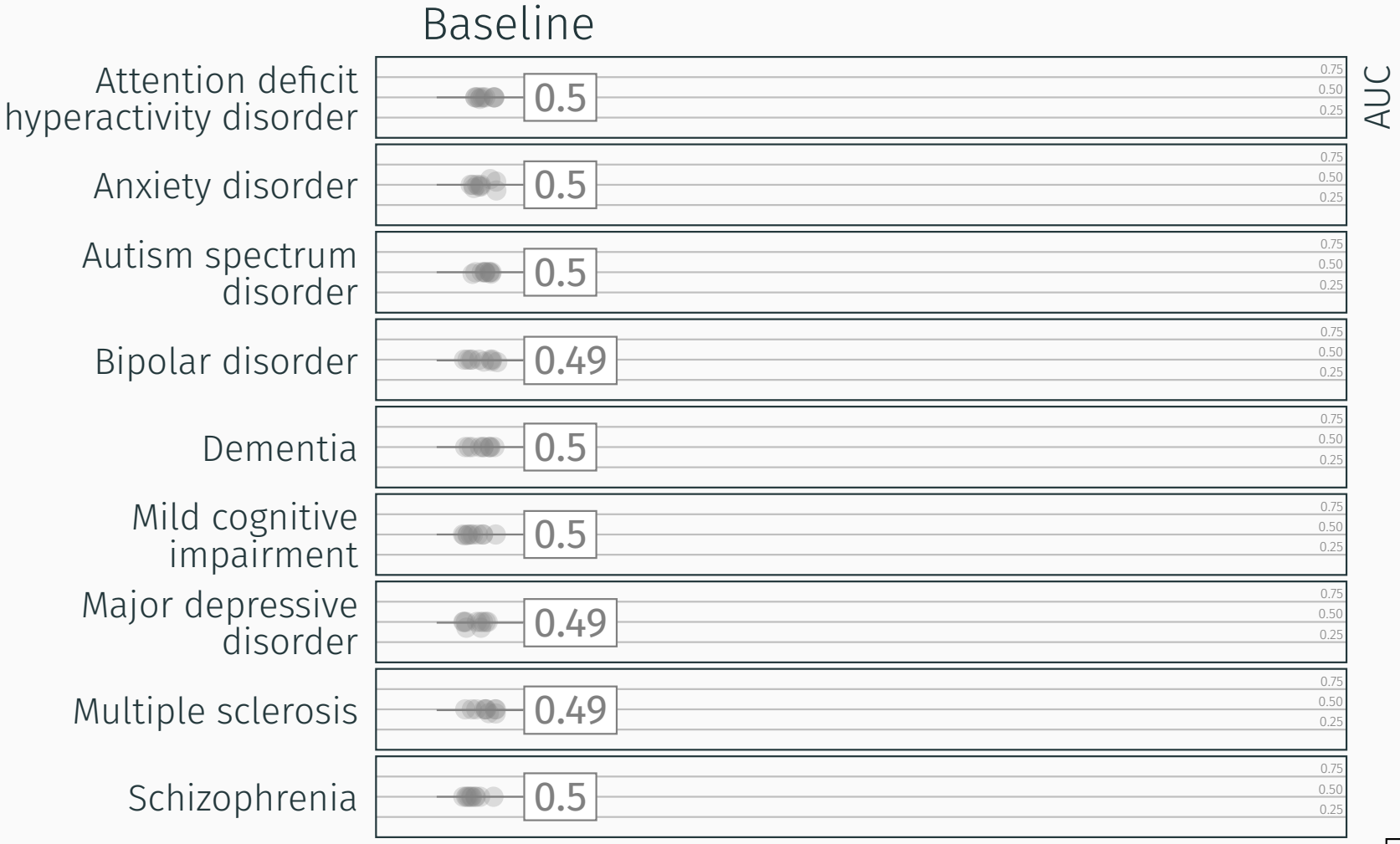
Explainable brain age: Results



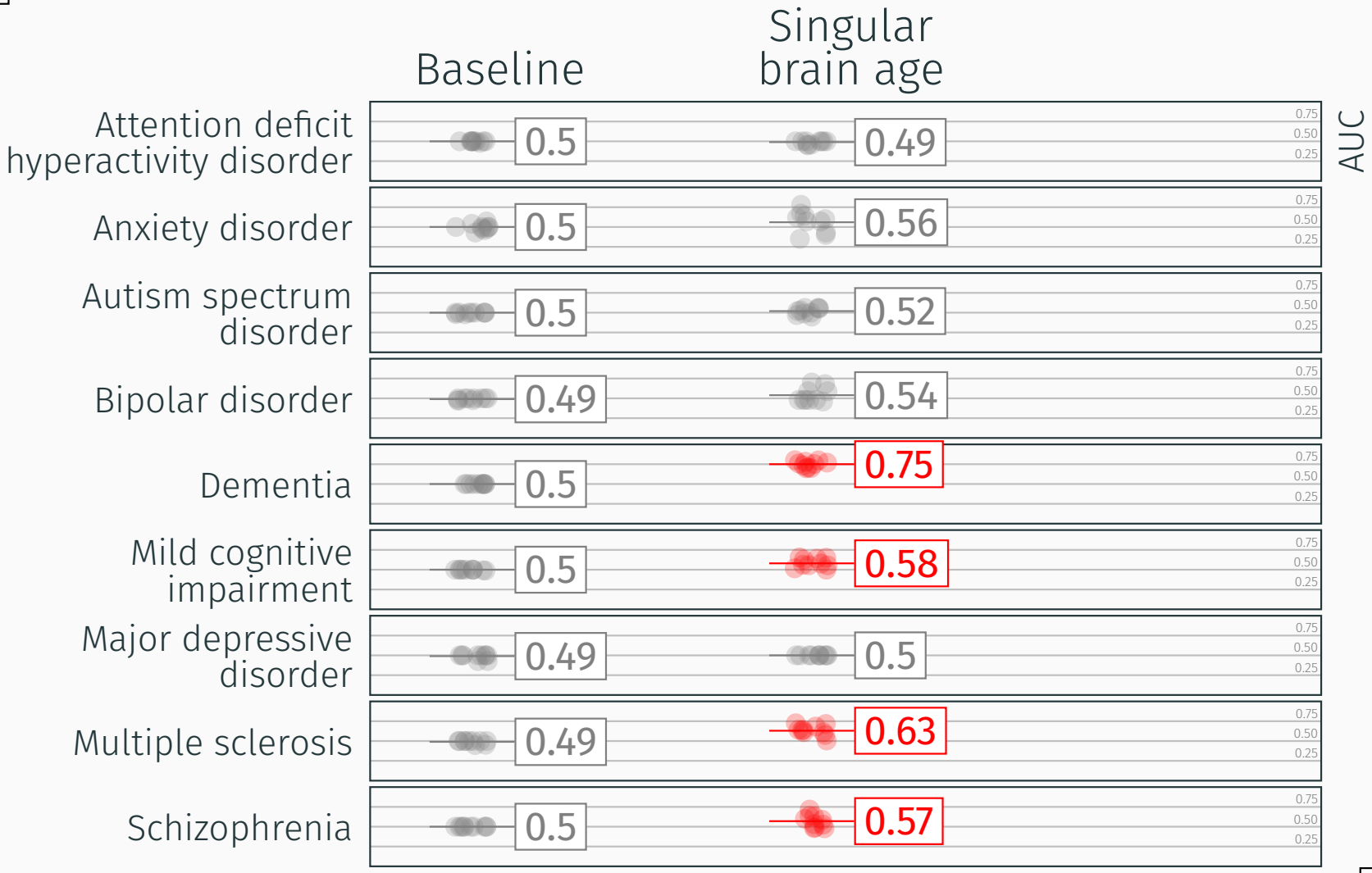
Younger appearing

Older appearing

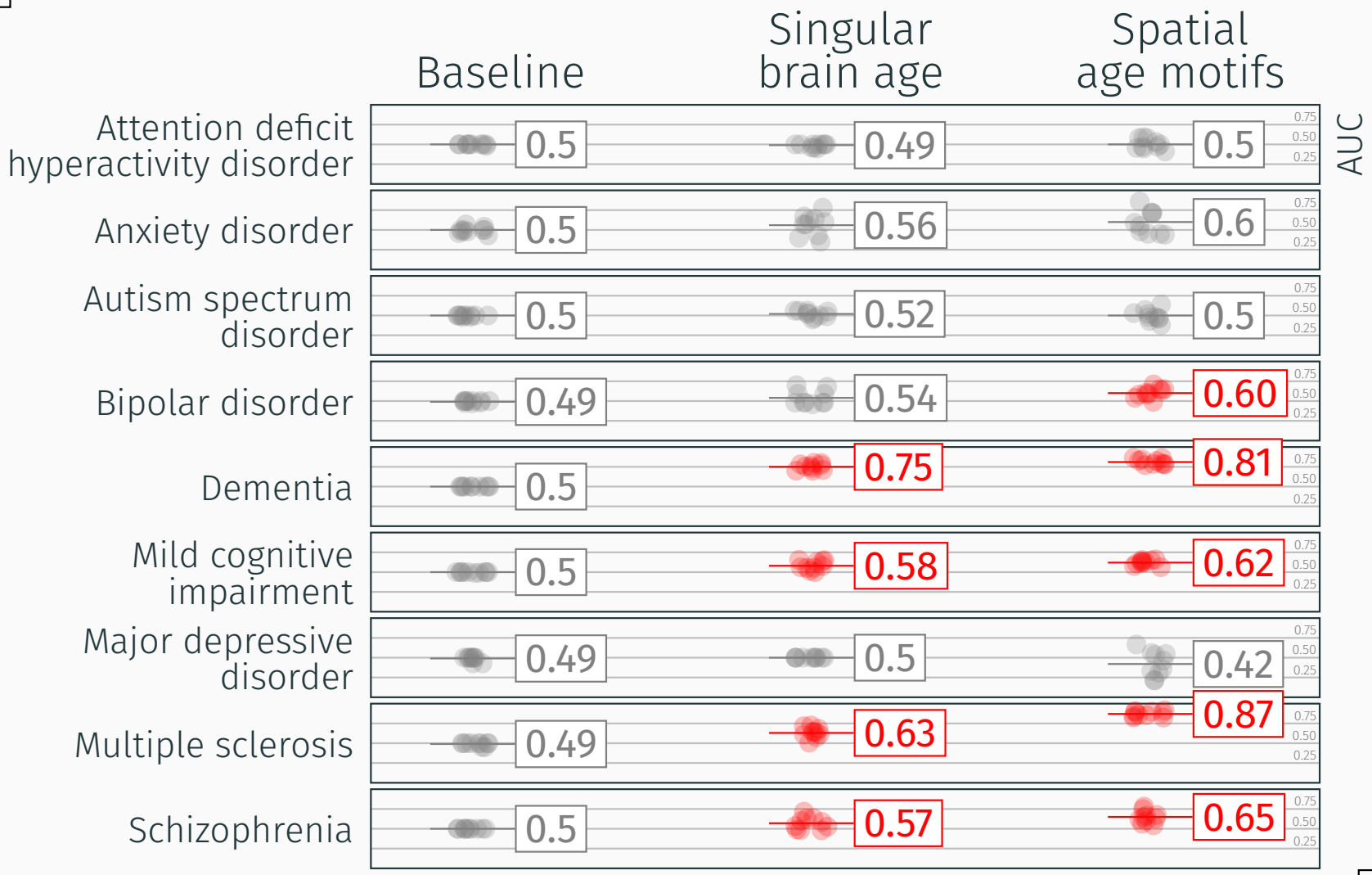
Explainable brain age: Results



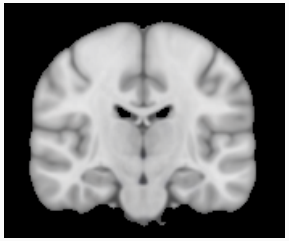
Explainable brain age: Results

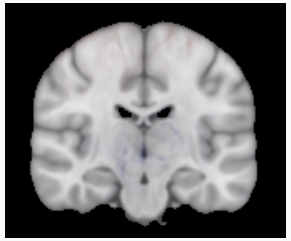


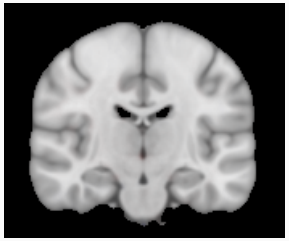
Explainable brain age: Results

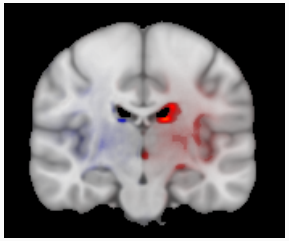


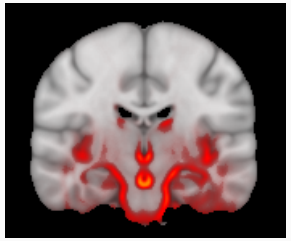
Explainable brain age: Results

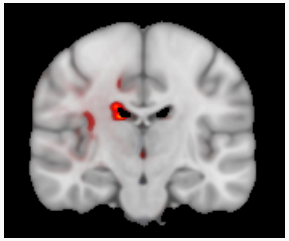

Attention deficit hyperactivity disorder

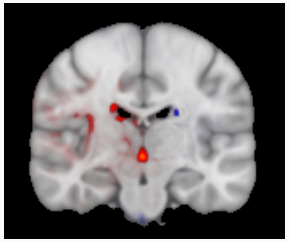

Anxiety disorder

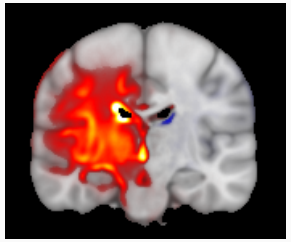

Autism spectrum disorder

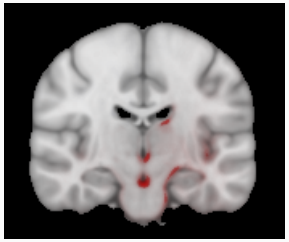

Bipolar disorder


Dementia

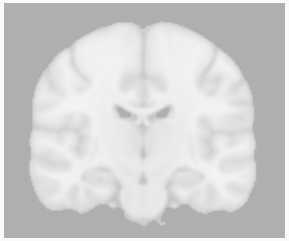

Schizophrenia


Major depressive disorder

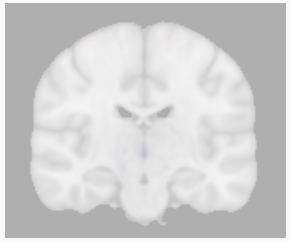

Multiple sclerosis


Mild cognitive impairment

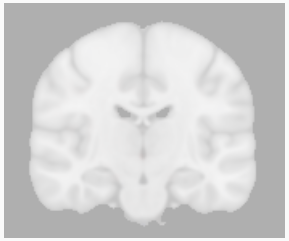
Explainable brain age: Results



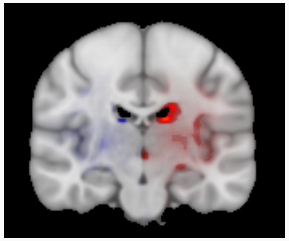
Attention deficit hyperactivity disorder



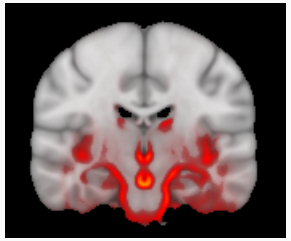
Anxiety disorder



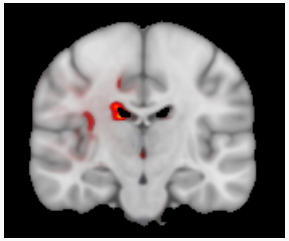
Autism spectrum disorder



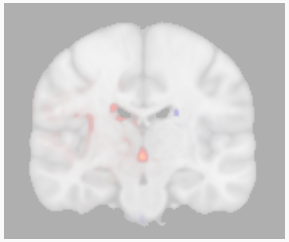
Bipolar disorder



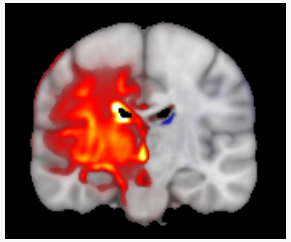
Dementia



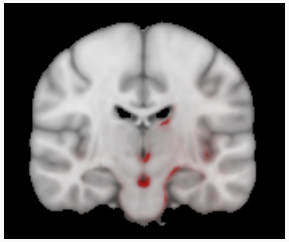
Schizophrenia



Major depressive disorder

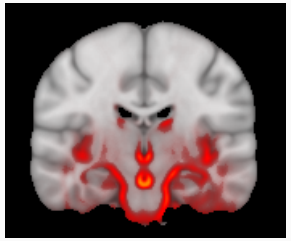


Multiple sclerosis



Mild cognitive impairment

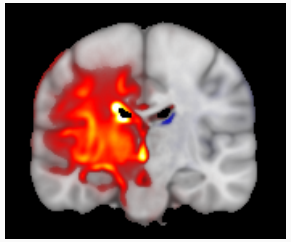
Explainable brain age: Results



Dementia

- Temporal pole
- Left amygdala
- Parahippocampal gyrus

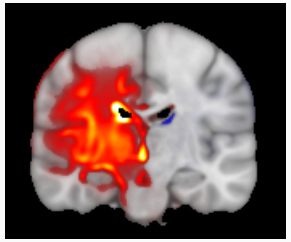
Explainable brain age: Results



Multiple sclerosis

- Right pallidum
- Right thalamus
- Right putamen

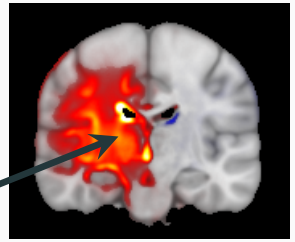
Explainable brain age: Results



Multiple sclerosis

- Right pallidum
- Right thalamus
- Right putamen

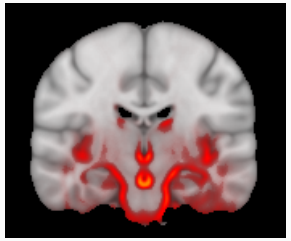
Explainable brain age: Results



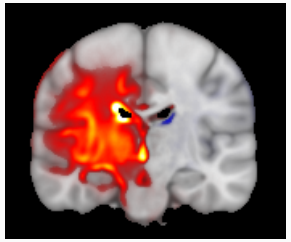
Multiple sclerosis

- Right pallidum
- Right thalamus
- Right putamen

Explainable brain age: Results

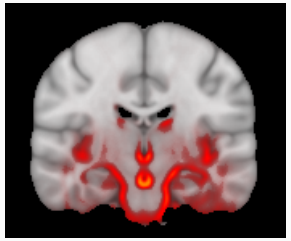
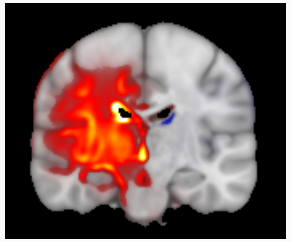


Dementia



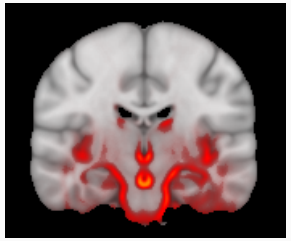
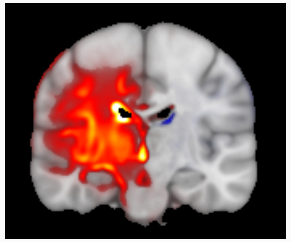
Multiple sclerosis

Explainable brain age: Results

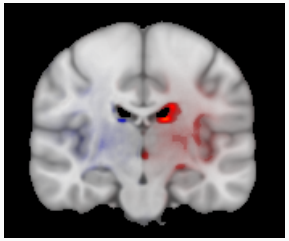
	AUC	
	Singular brain age	Spatial age motifs
 Dementia	0.75	0.81
 Multiple sclerosis	0.63	0.87

Explainable brain age: Results

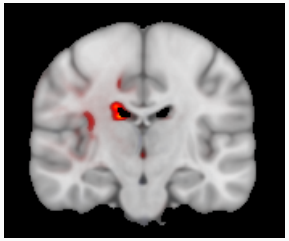
AUC

	Singular brain age		Spatial age motifs
 Dementia	0.75	$\xrightarrow{0.06}$	0.81
 Multiple sclerosis	0.63	$\xrightarrow{0.24}$	0.87

Explainable brain age: Results

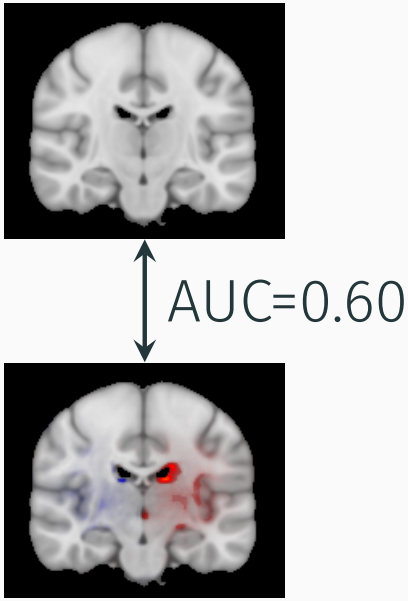


Bipolar disorder

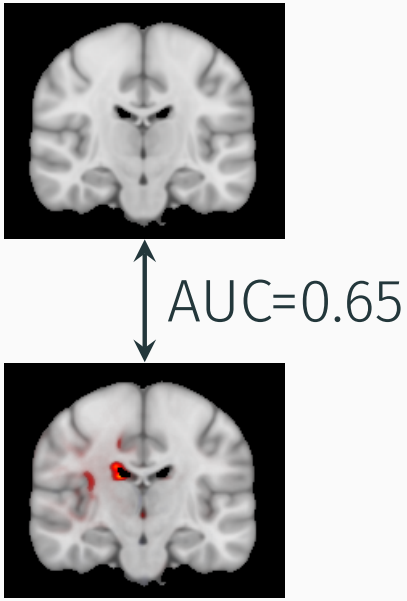


Schizophrenia

Explainable brain age: Results

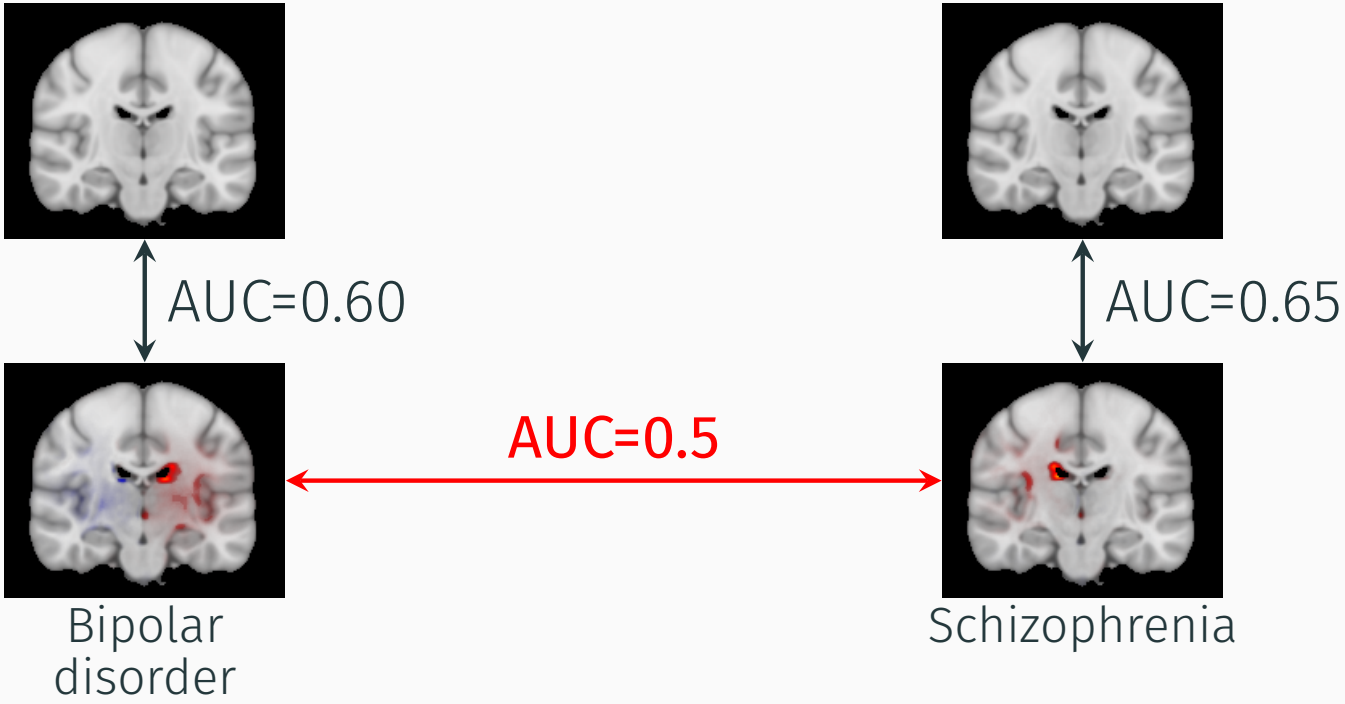


Bipolar disorder



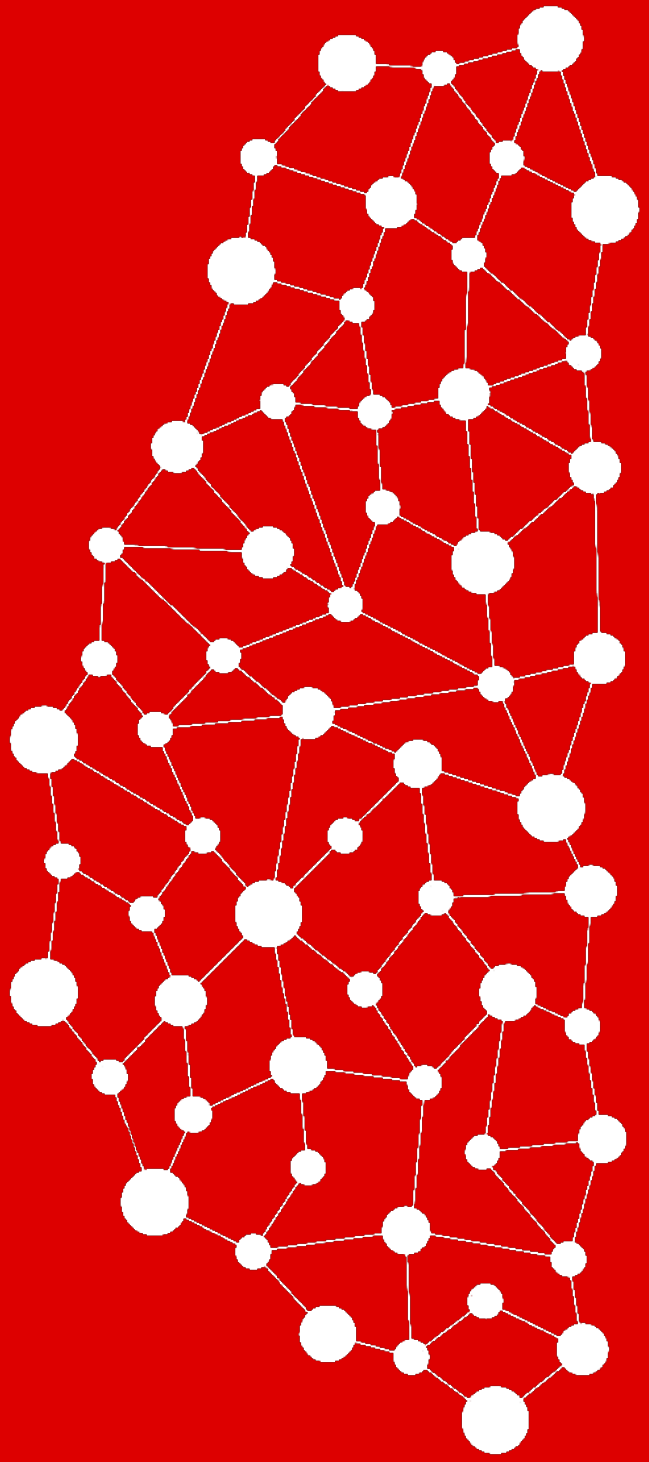
Schizophrenia

Explainable brain age: Results



Thank you for your attention!

estenhl@uio.no



UNIVERSITY
OF OSLO