

Exploring brain heterogeneity in patients with neuropsychiatric disorders using explainable artificial intelligence



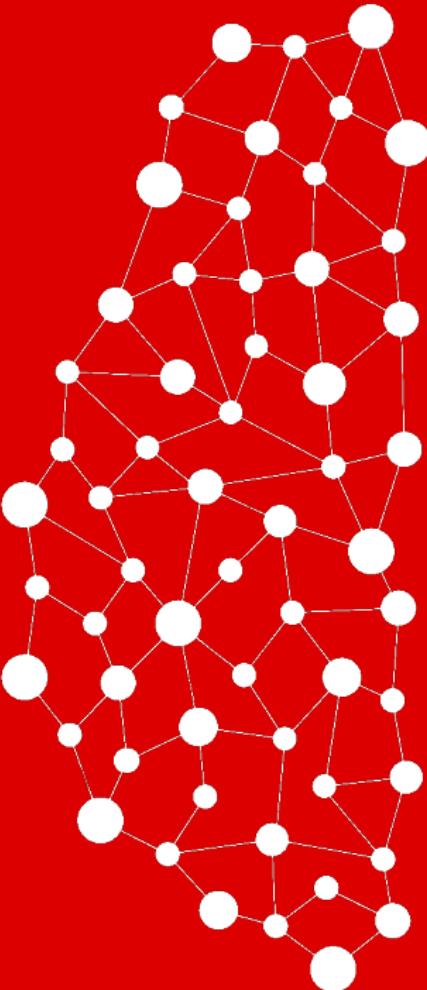
Esten H. Leonardsen

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

Chief Scientific Officer, baba.vision



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Overview

1. Background
2. Explainable artificial intelligence for dementia-prediction
3. Explainable brain age predictions



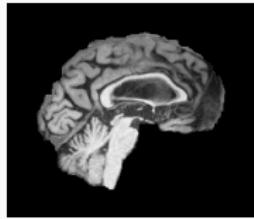
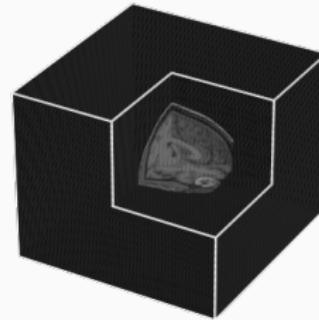
Background: Predictive clinical neuroscience



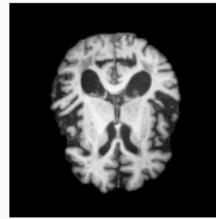
Background: Predictive clinical neuroscience



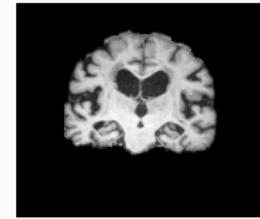
Structural Magnetic
Resonance Imaging (MRI) scans



Side



Above



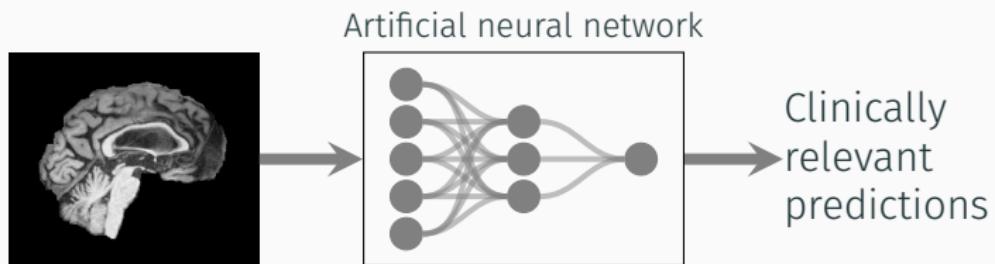
Front



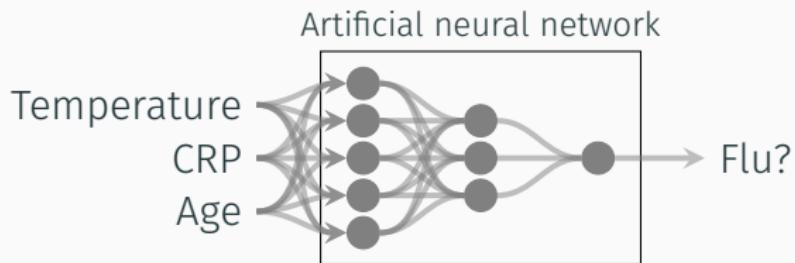
Background: Explainable artificial intelligence



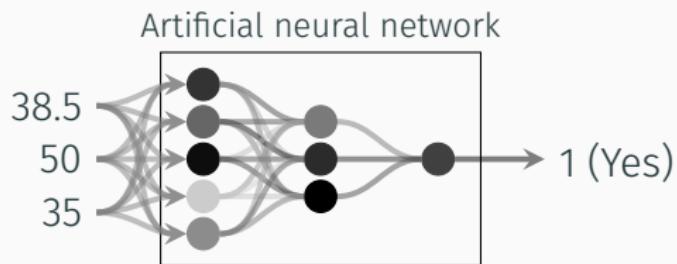
Background: Explainable artificial intelligence



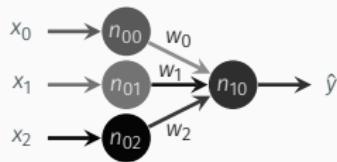
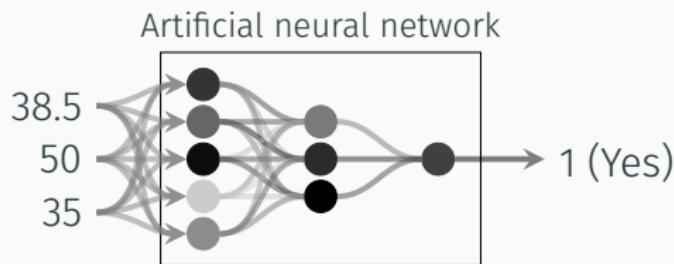
Background: Explainable artificial intelligence



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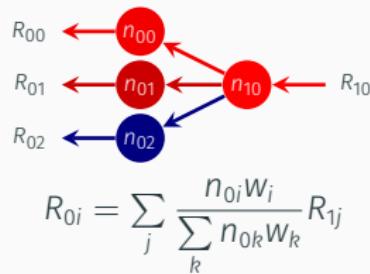
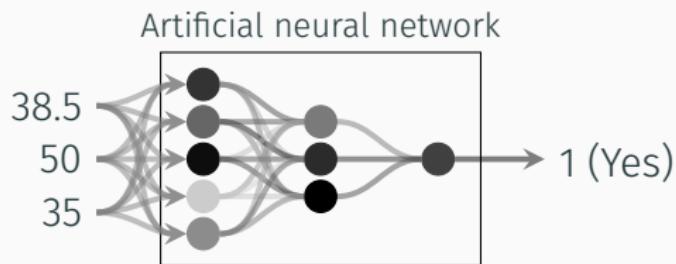
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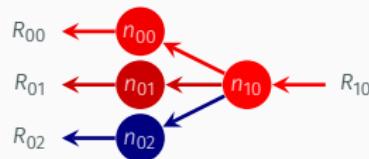
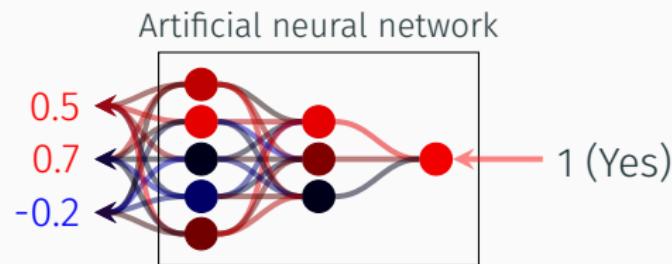
$$\hat{y} = f \left(\sum_i^N w_i \cdot n_{0i} \right)$$



Background: Explainable artificial intelligence



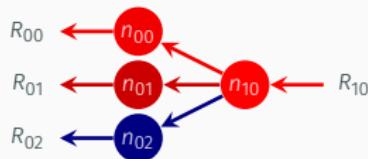
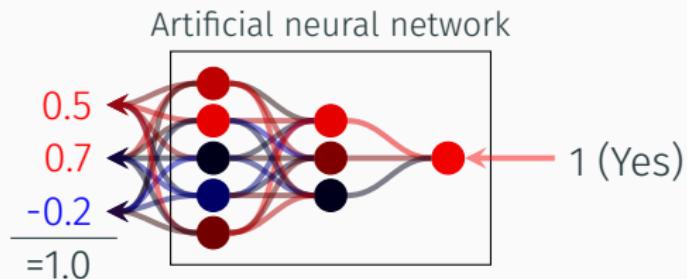
Background: Explainable artificial intelligence



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



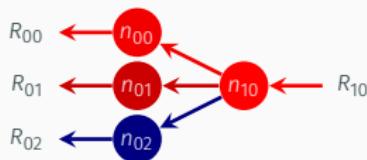
Background: Explainable artificial intelligence



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



Background: Explainable artificial intelligence



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



Explainability and dementia



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Explainability and dementia: Dataset



FEMALE

MALE

55

60

65

70

75

80

85

90

95

n=1708

?? Controls
?? Patients



Explainability and dementia: Dataset



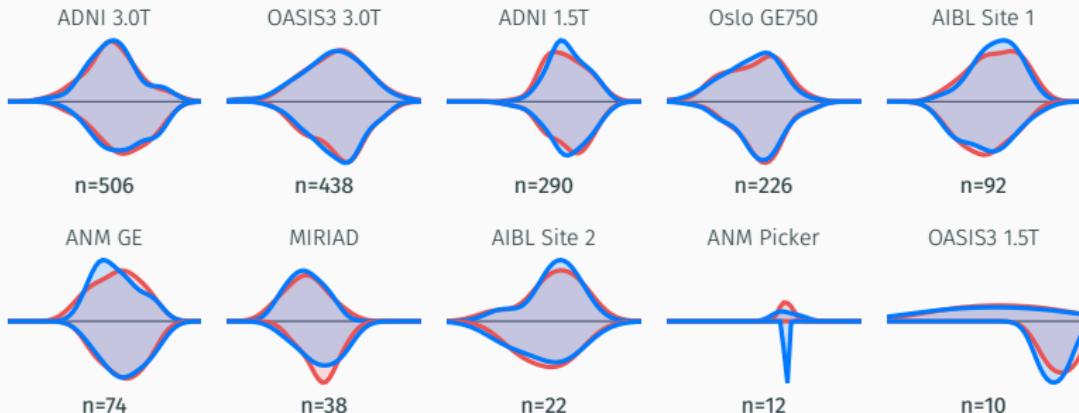
FEMALE

MALE

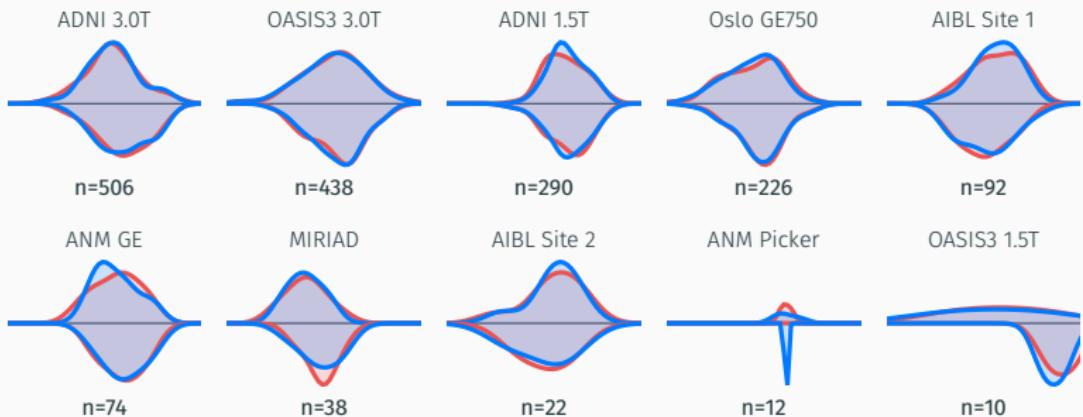
55 60 65 70 75 80 85 90 95

n=1708

?? Controls
?? Patients



Explainability and dementia: Dataset



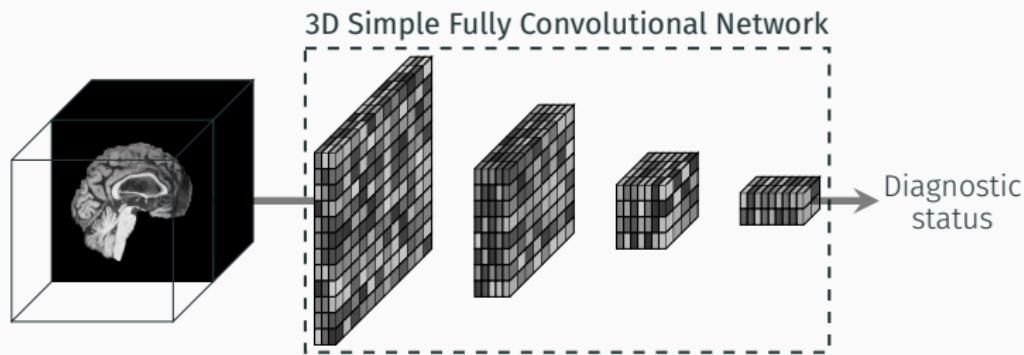
Explainability and dementia: Modelling



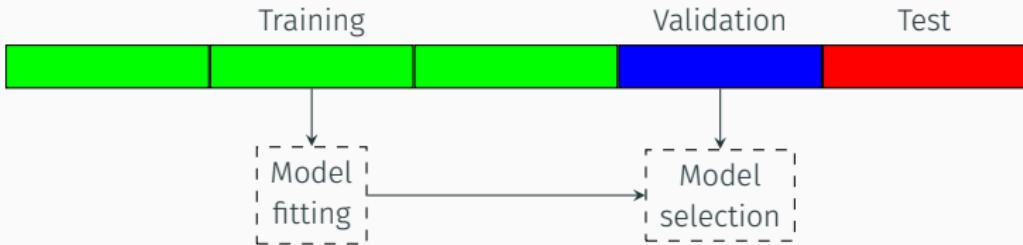
Explainability and dementia: Modelling



Explainability and dementia: Modelling



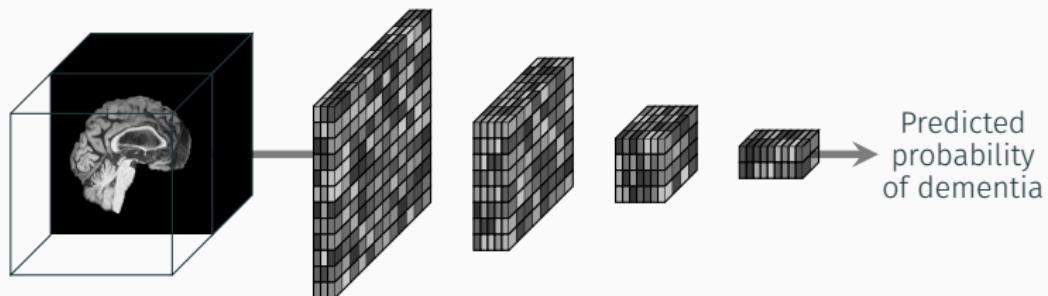
Explainability and dementia: Modelling



Hyperparameter	Values
Weight decay	$\{10^{-2}, 10^{-3}\}$
Dropout	{0.25, 0.5}
Learning rate schedule	{stepwise, cyclic, one-cycle}
Augmentations	{light, heavy}



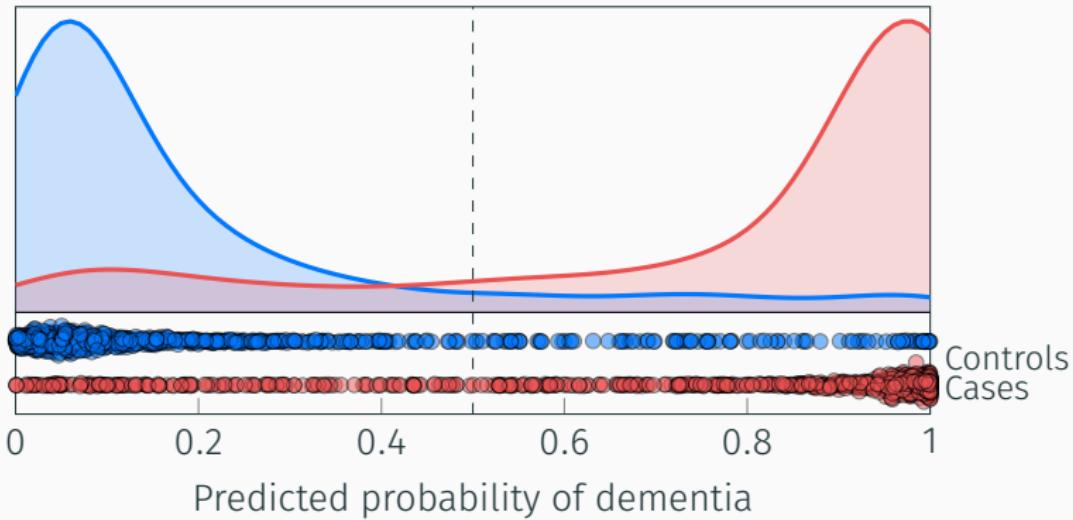
Explainability and dementia: Modelling



Explainability and dementia: Modelling



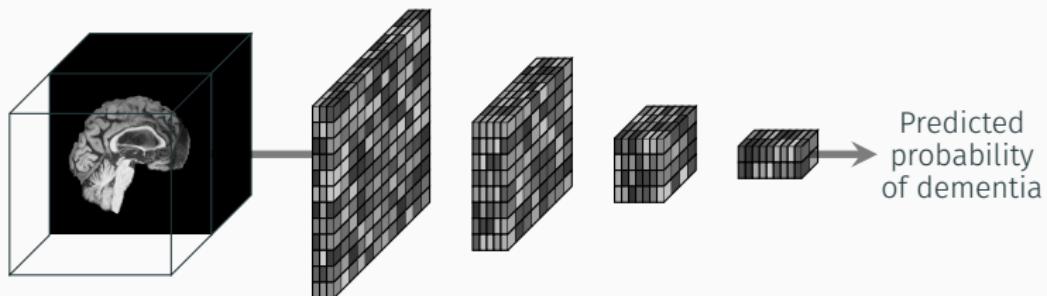
Explainability and dementia: Modelling



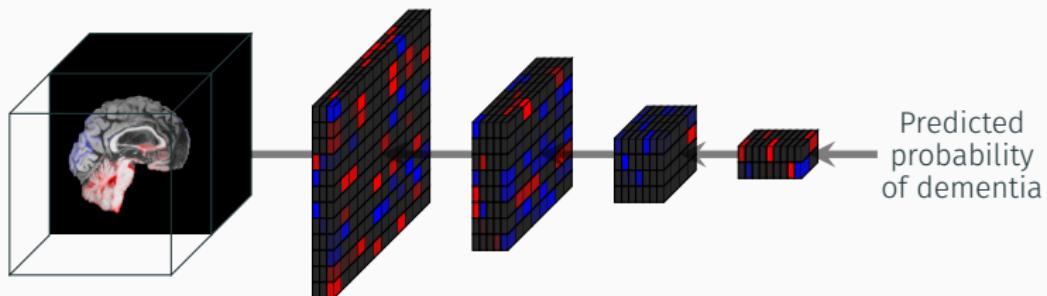
AUC=0.91, balanced accuracy=85%



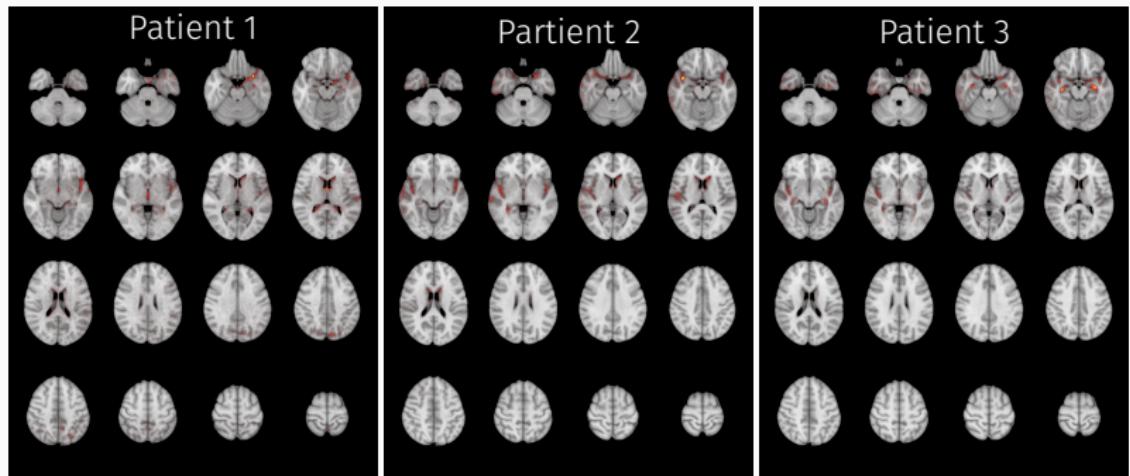
Explainability and dementia: Modelling



Explainability and dementia: Modelling



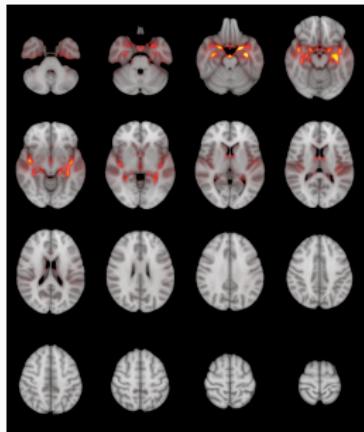
Explainability and dementia: Validation



Explainability and dementia: Validation



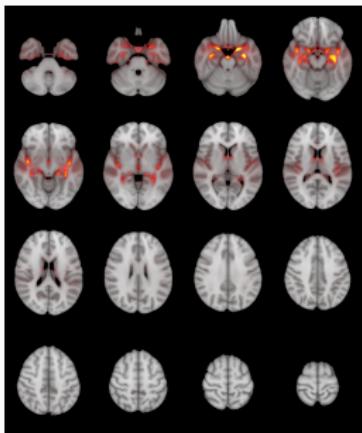
LRP



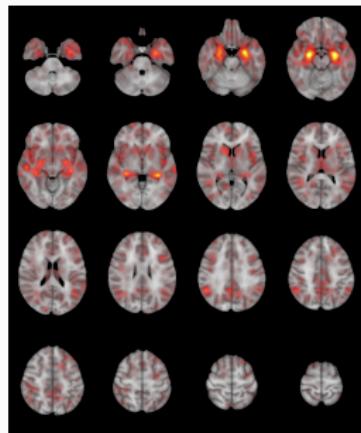
Explainability and dementia: Validation



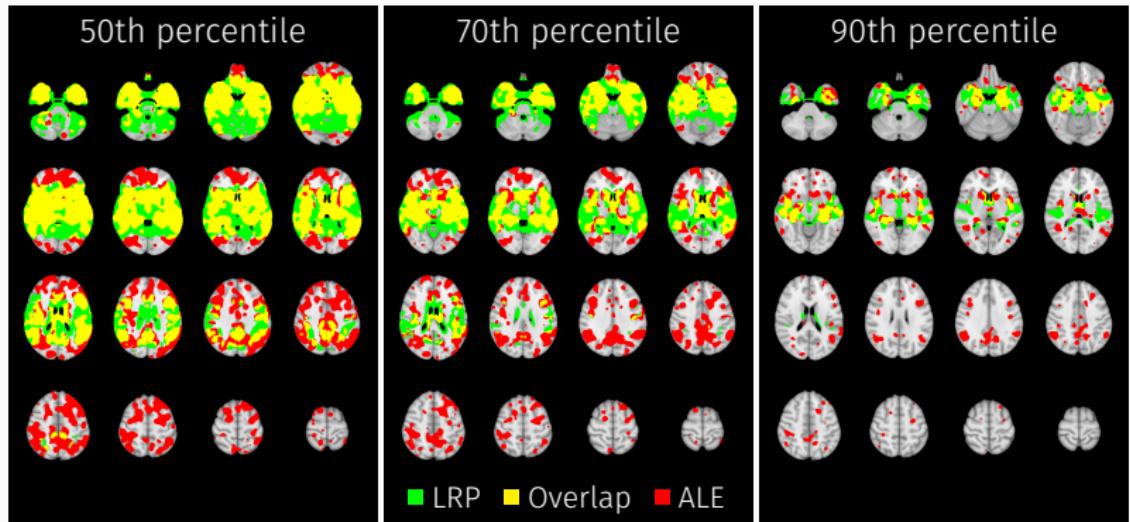
LRP



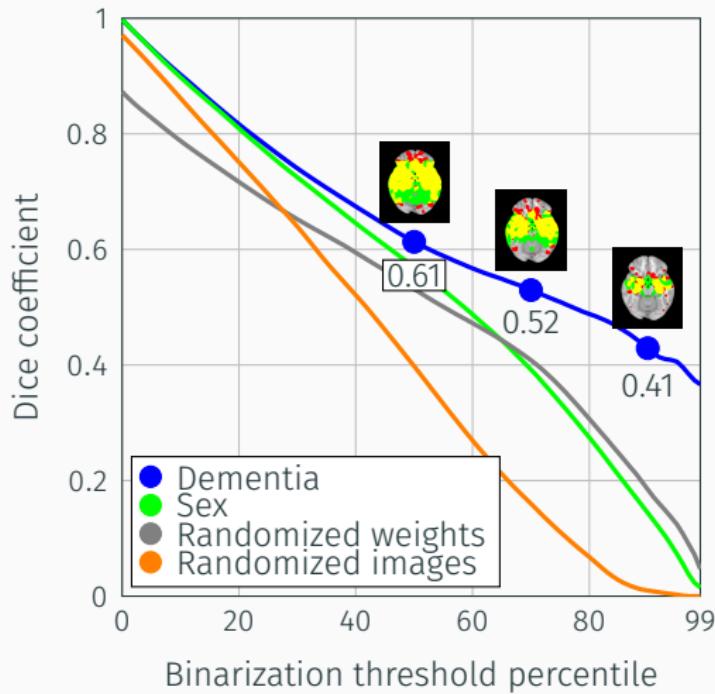
GingerALE



Explainability and dementia: Validation



Explainability and dementia: Validation



Explainability and dementia: Validation



AOPC



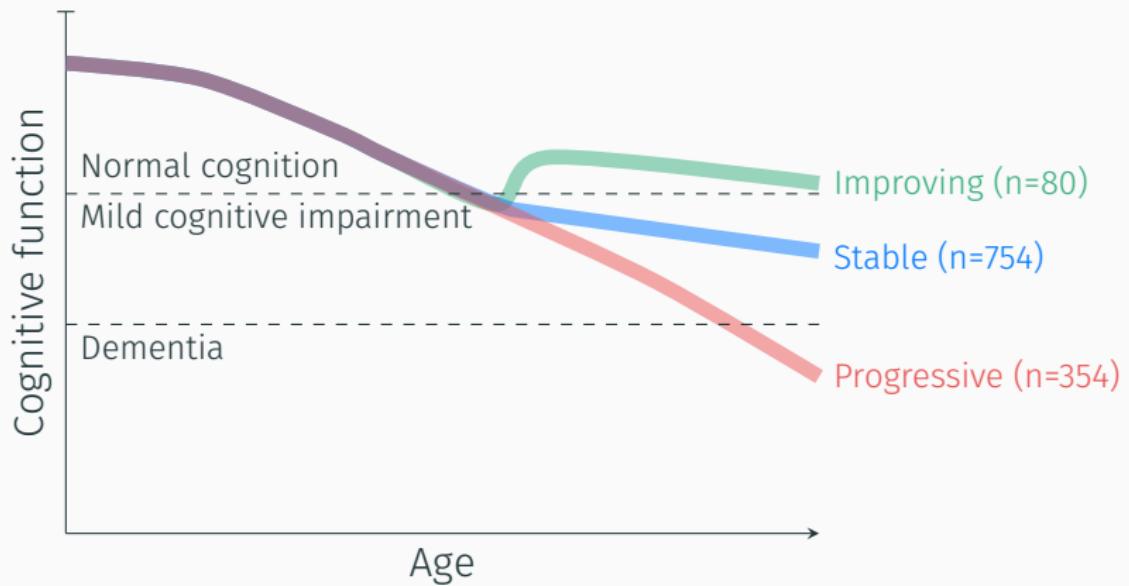
Explainability and dementia: Application



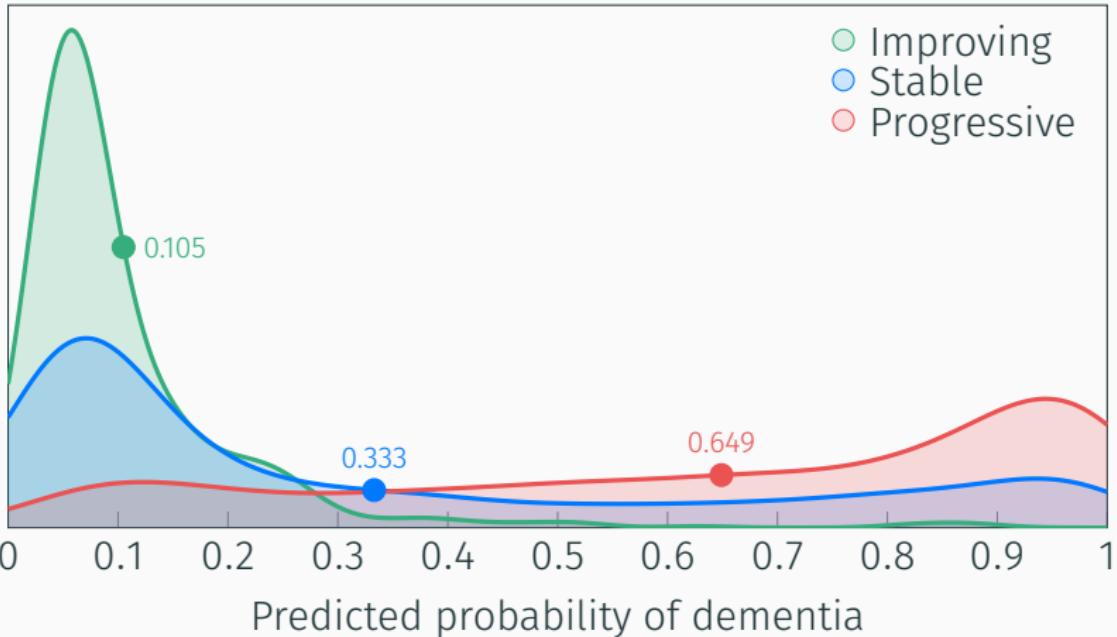
MCI dataset



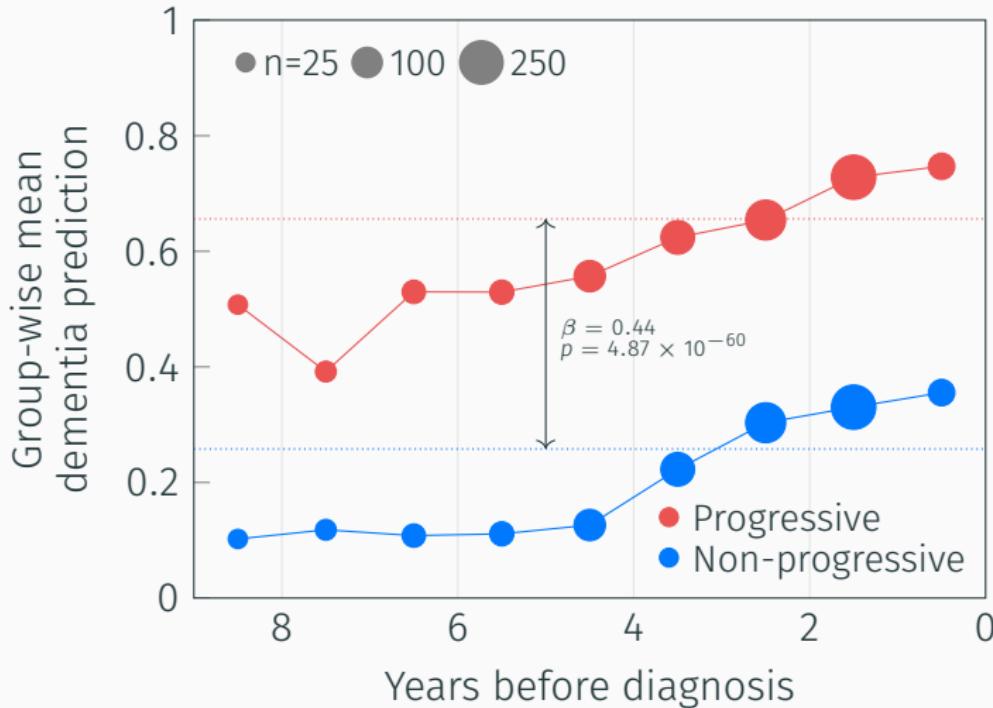
Explainability and dementia: Application



Explainability and dementia: Application



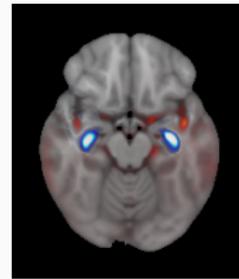
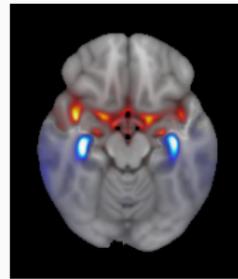
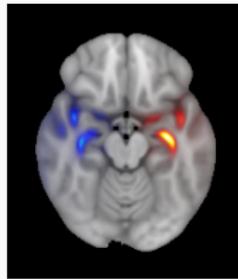
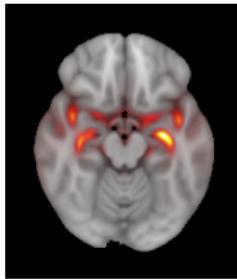
Explainability and dementia: Application



Explainability and dementia: Application



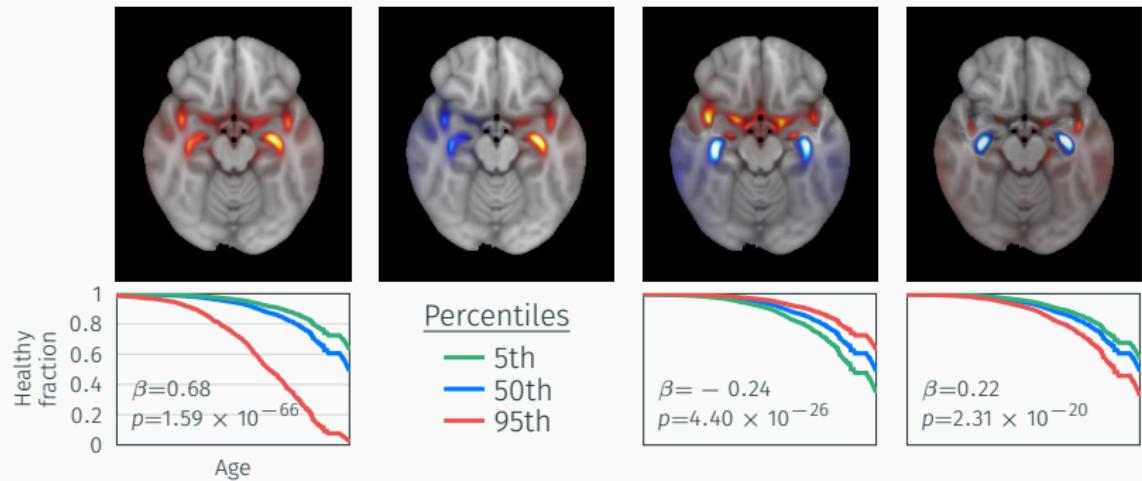
Component 0 Component 1 Component 2 Component 3



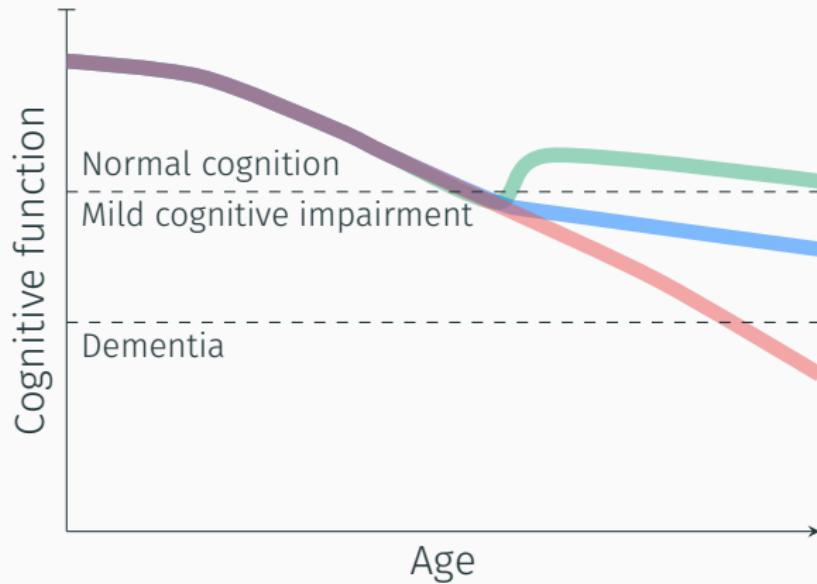
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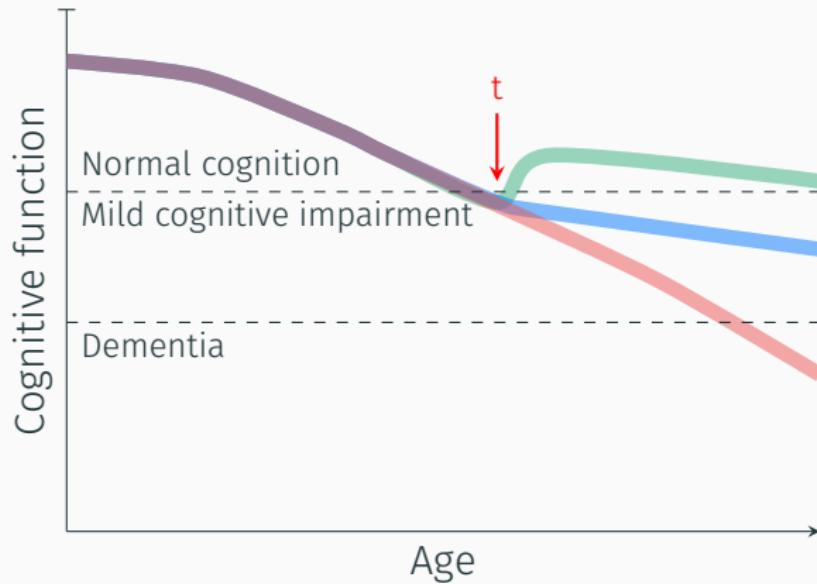
Component 0 Component 1 Component 2 Component 3



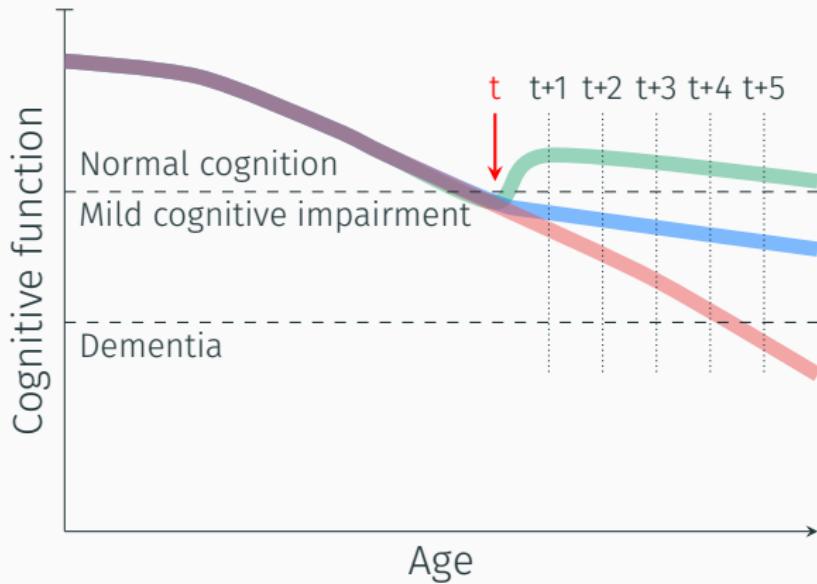
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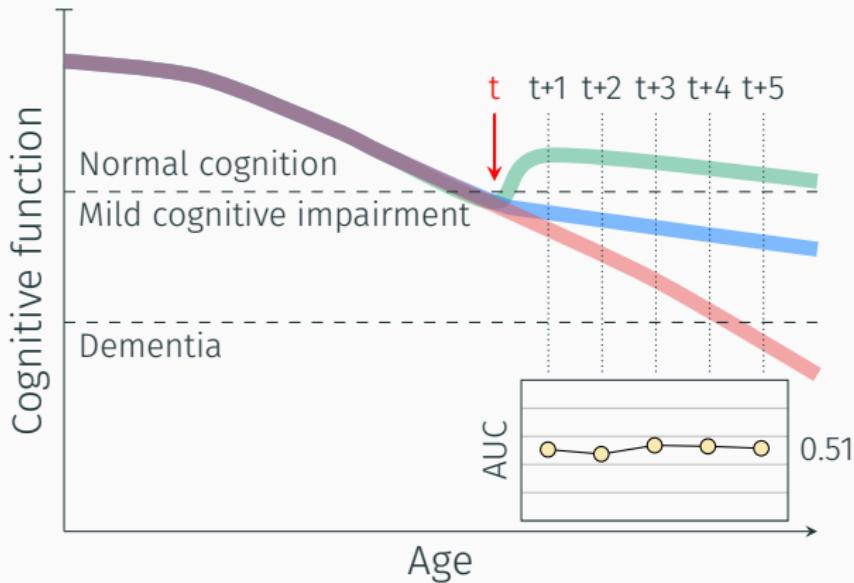
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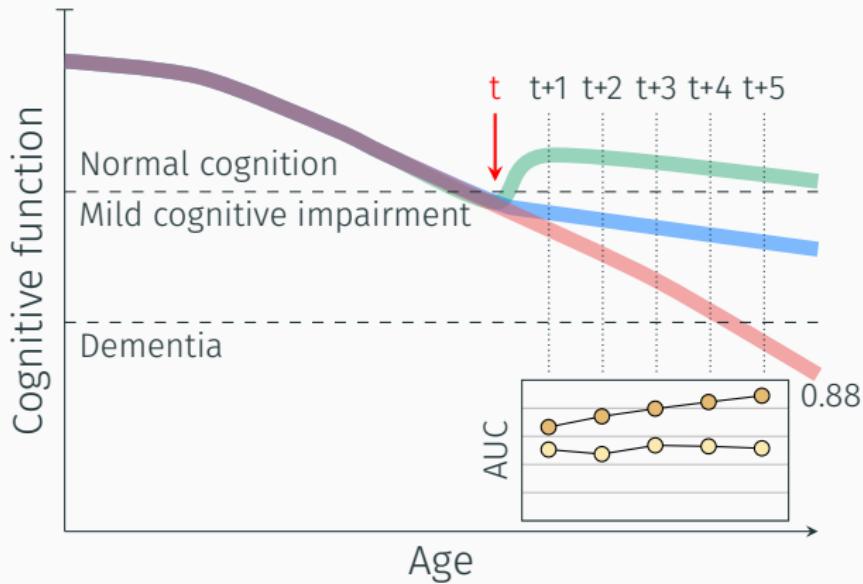
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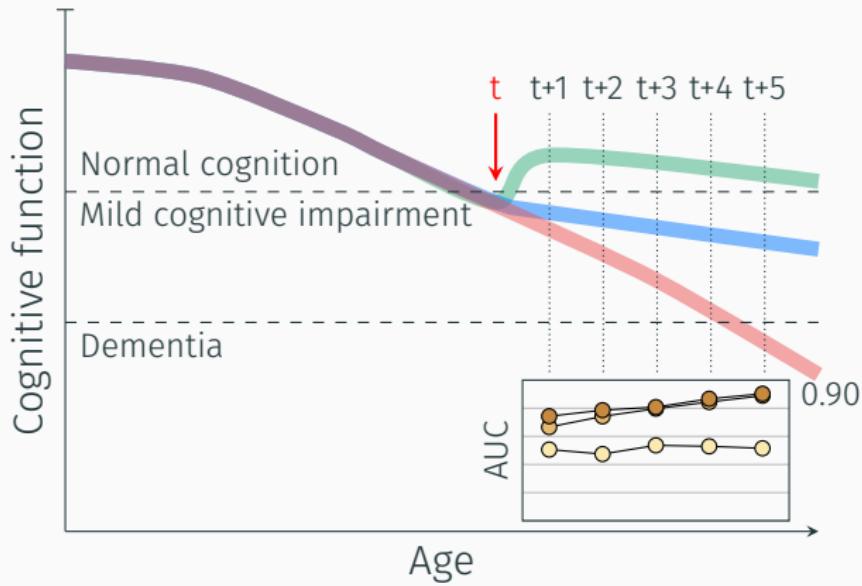
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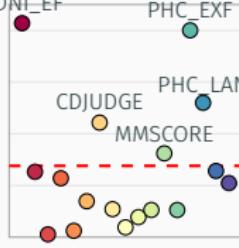
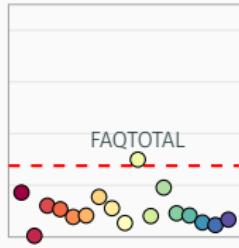
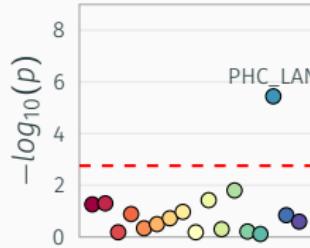
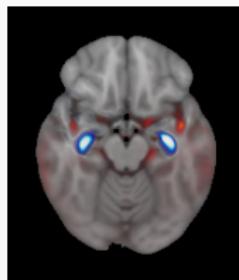
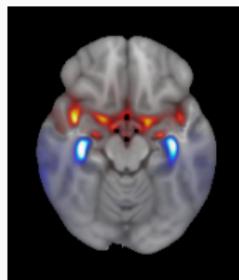
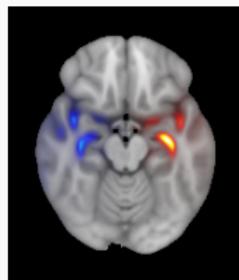
Explainability and dementia: Application



Explainability and dementia: Application



Explainability and dementia: Application



Explainability and dementia: Application



Morphological record

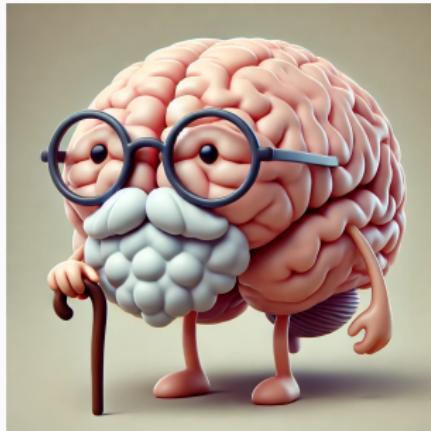


Explainable brain age



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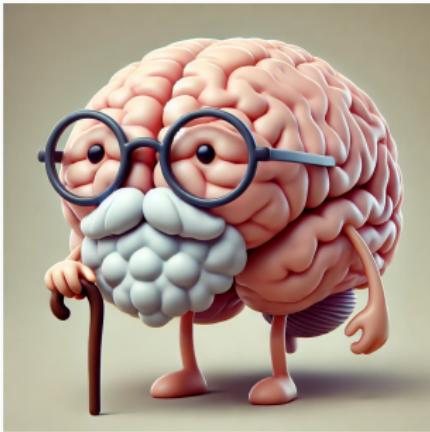
Explainable brain age: Motivation



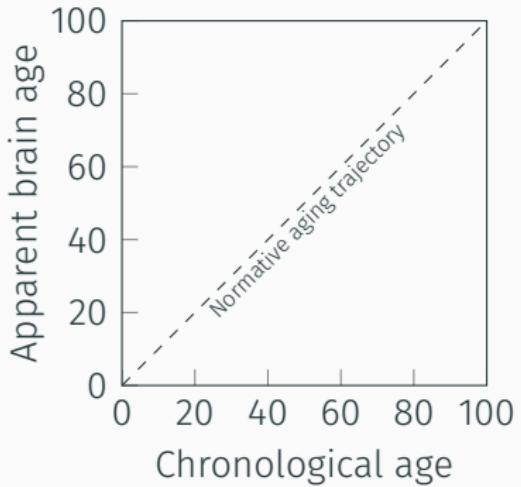
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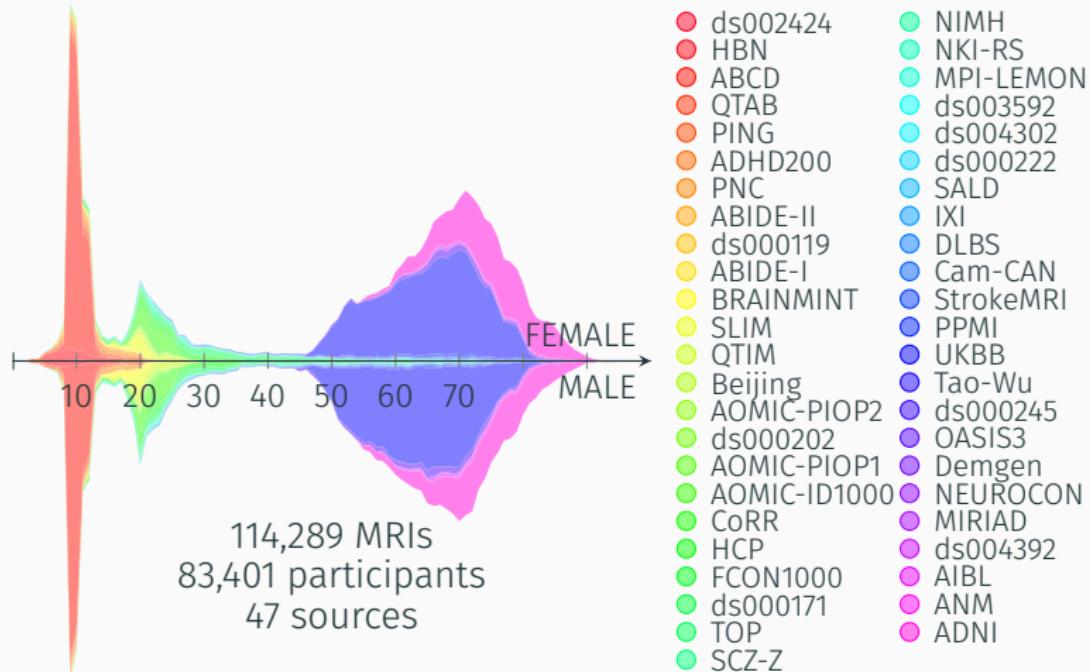
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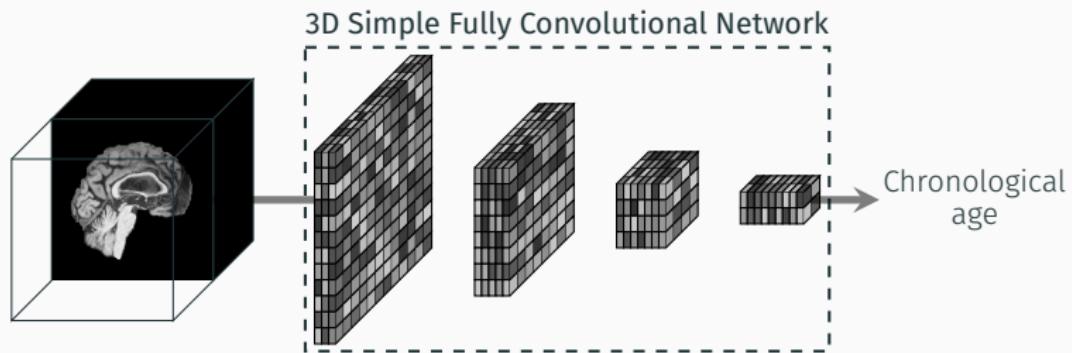
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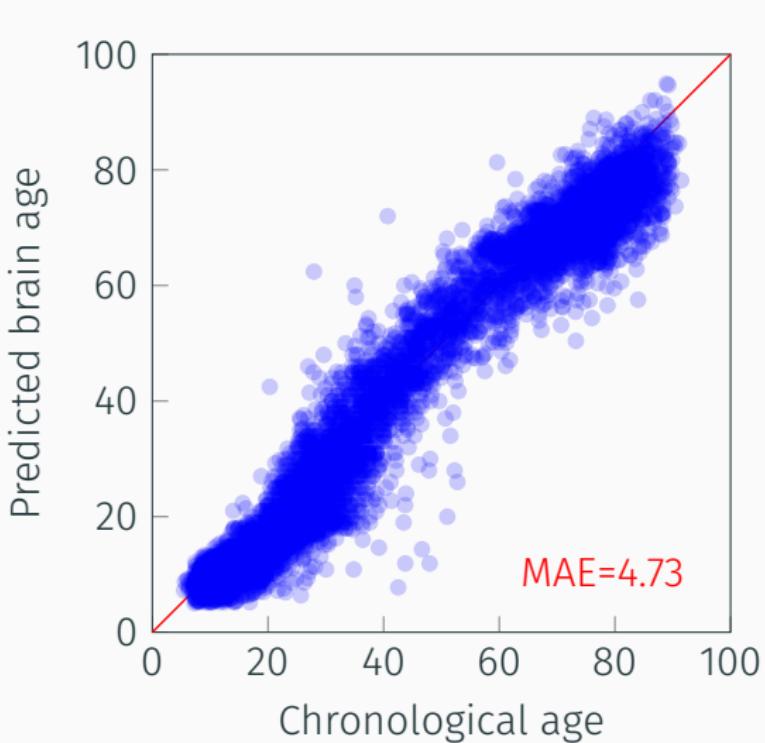
Explainable brain age: Motivation



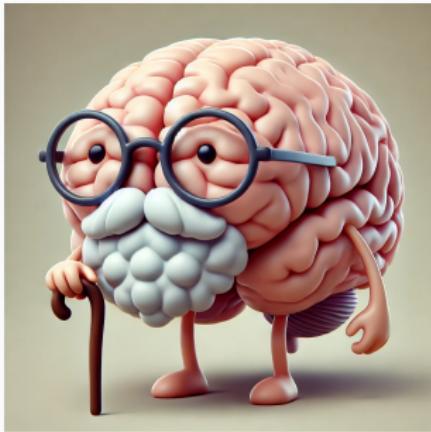
Explainable brain age: Motivation



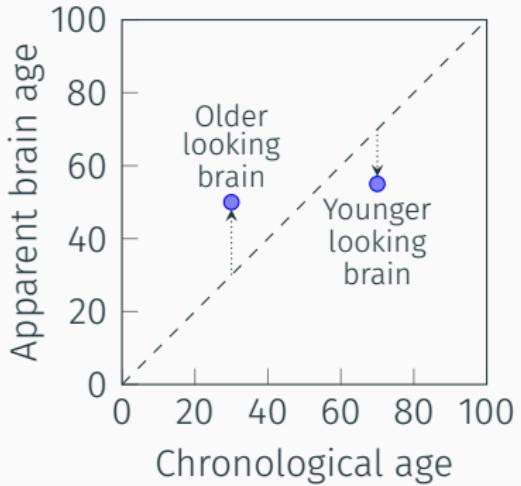
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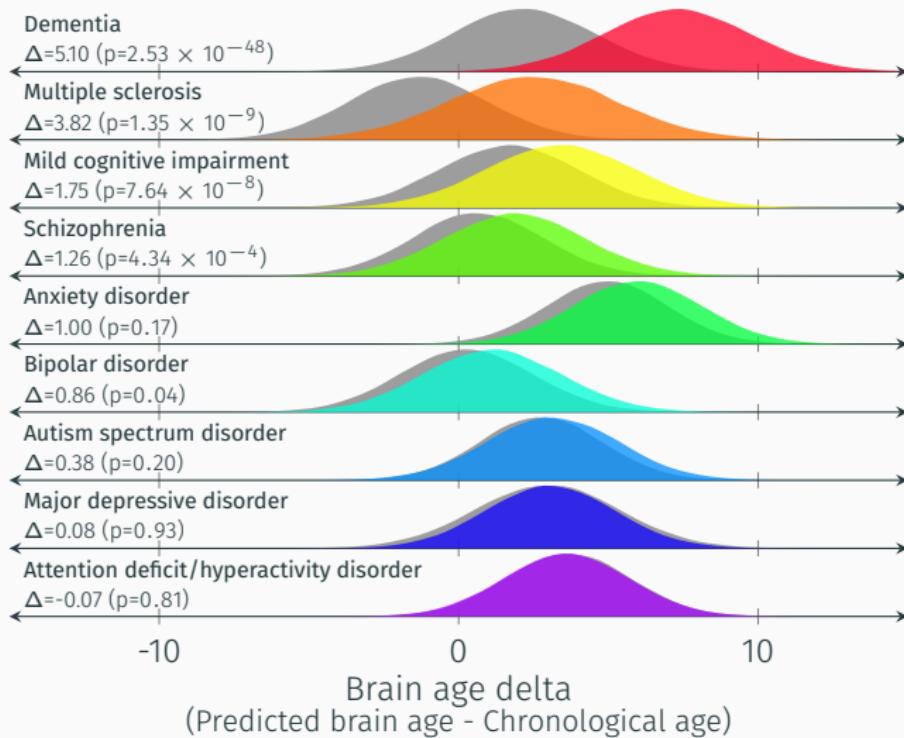
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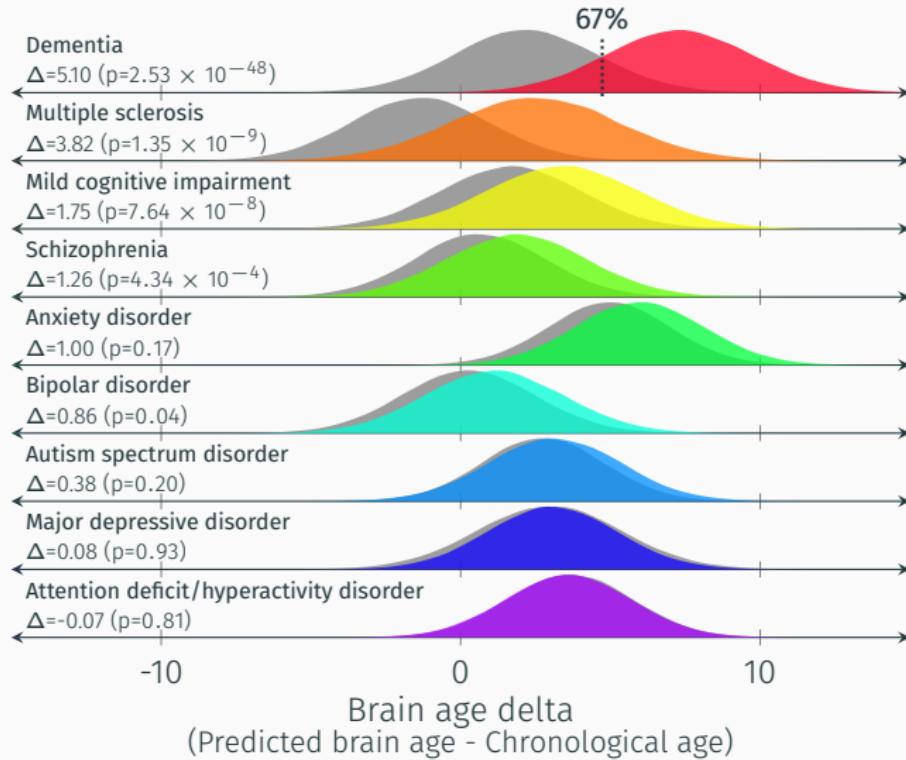
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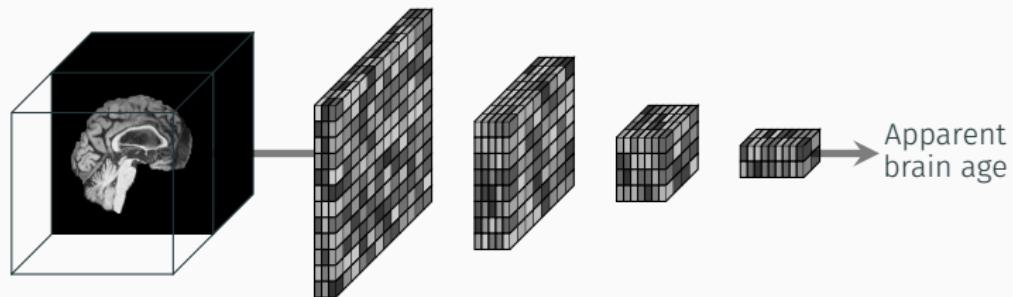
Explainable brain age: Motivation



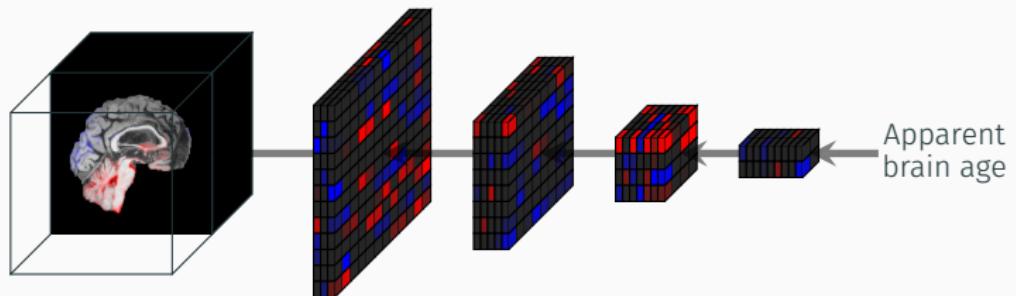
Explainable brain age: Motivation



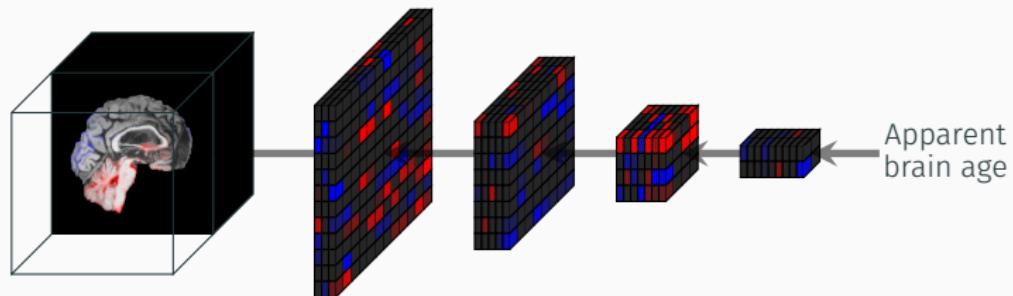
Explainable brain age: Methods



Explainable brain age: Methods



Explainable brain age: Methods



Filters



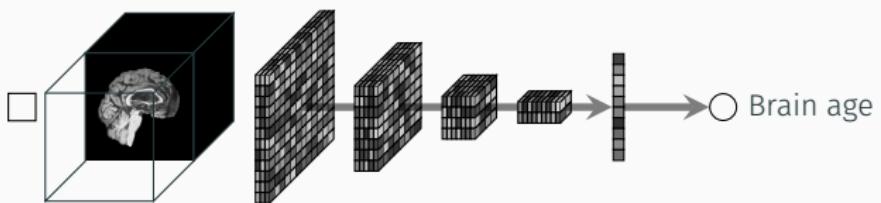
Explainable brain age: Methods



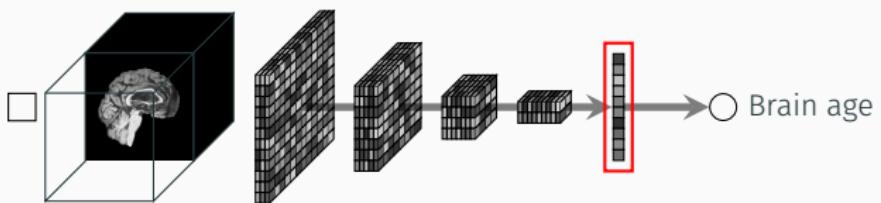
Feature correlation



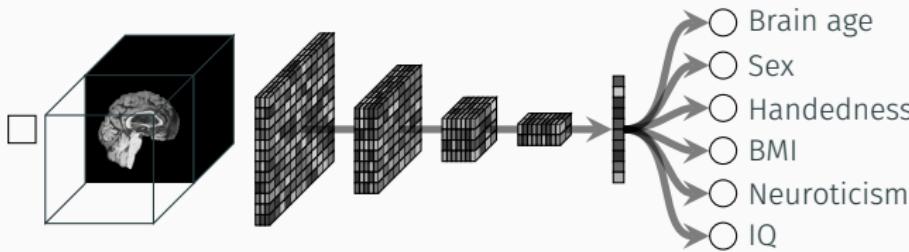
Explainable brain age: Methods



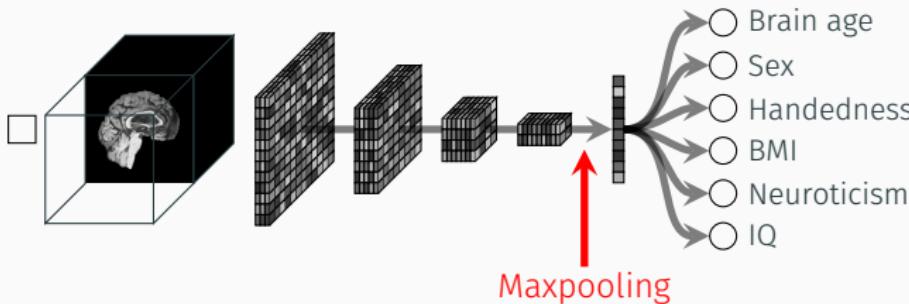
Explainable brain age: Methods



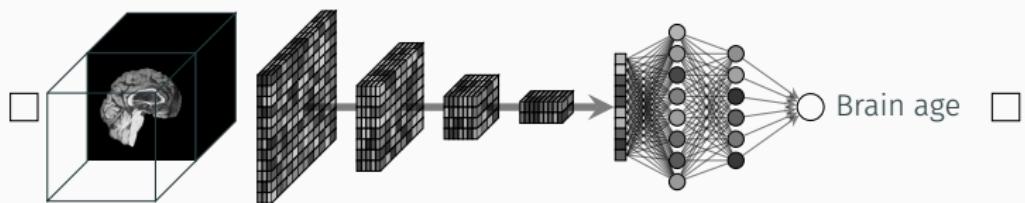
Explainable brain age: Methods



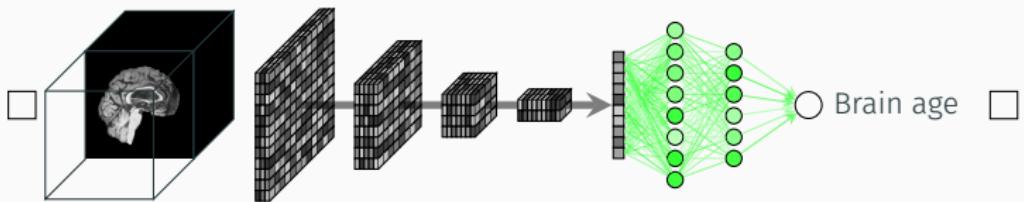
Explainable brain age: Methods



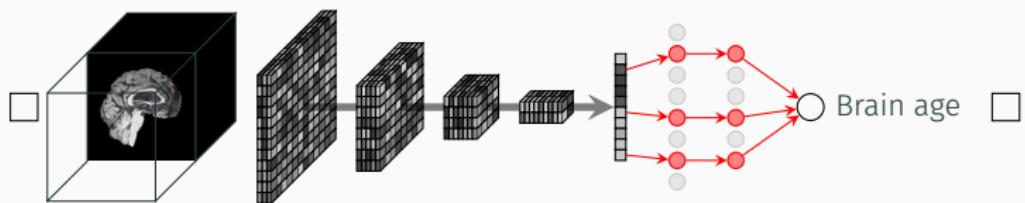
Explainable brain age: Methods



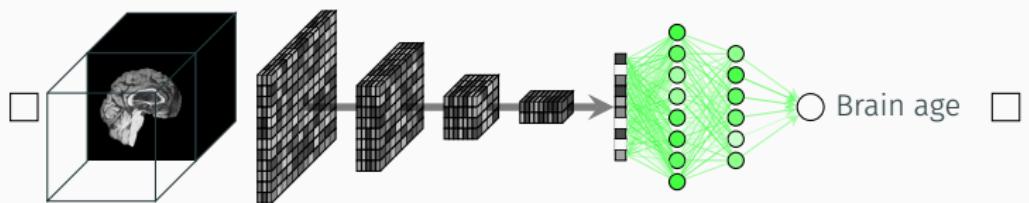
Explainable brain age: Methods



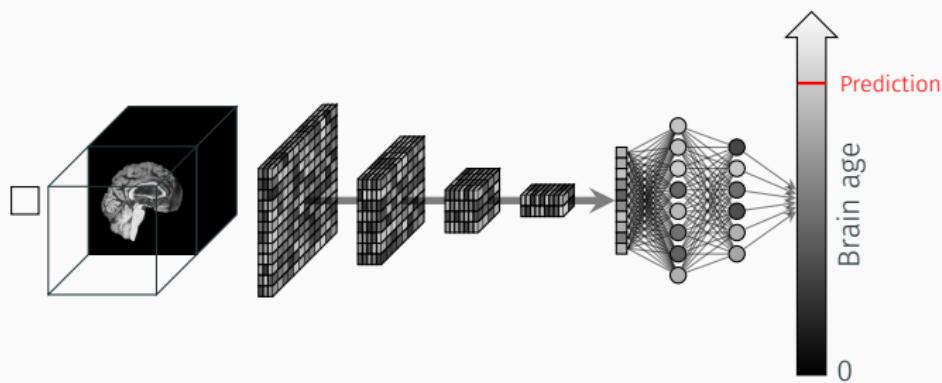
Explainable brain age: Methods



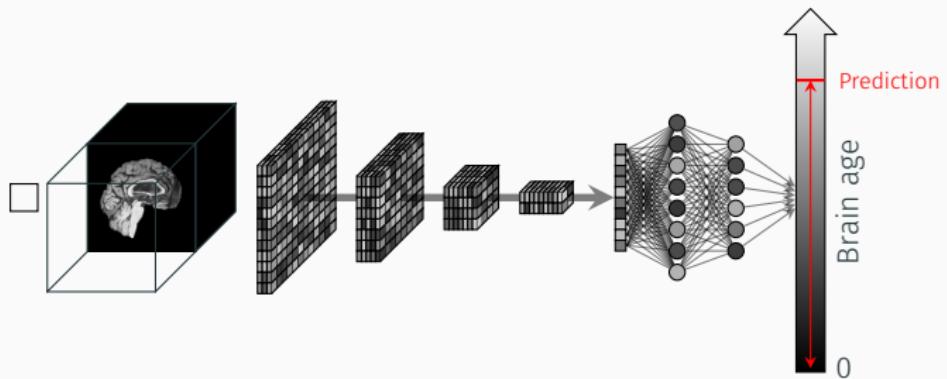
Explainable brain age: Methods



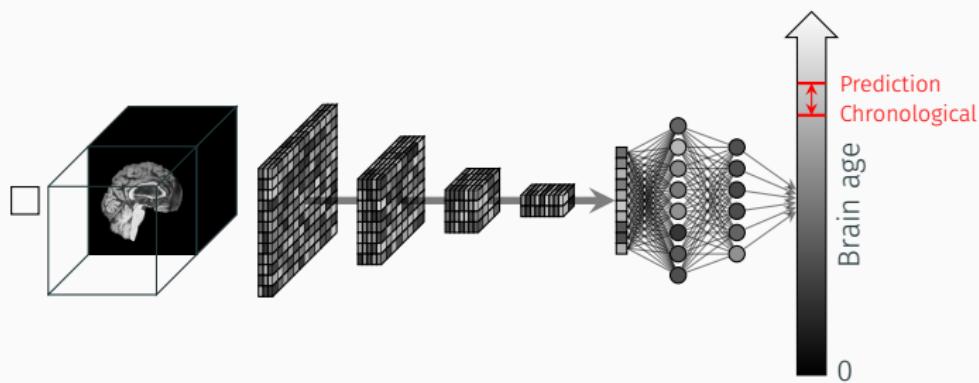
Explainable brain age: Methods



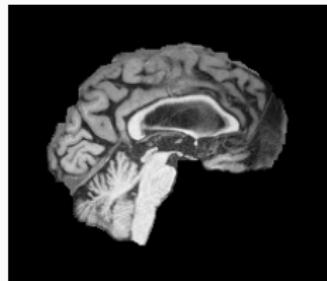
Explainable brain age: Methods



Explainable brain age: Methods



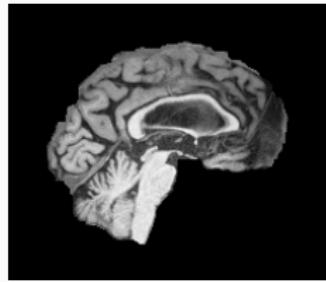
Explainable brain age: Methods



Age
62



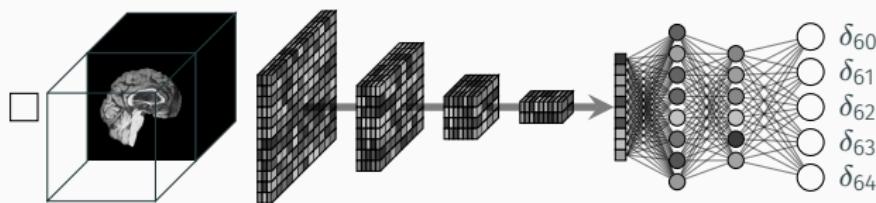
Explainable brain age: Methods



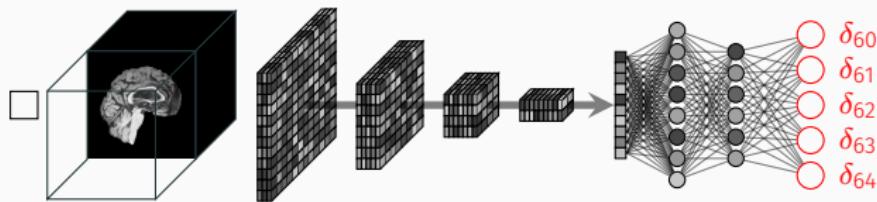
δ_{60}	δ_{61}	δ_{62}	δ_{63}	δ_{64}
2	1	0	-1	-2



Explainable brain age: Methods



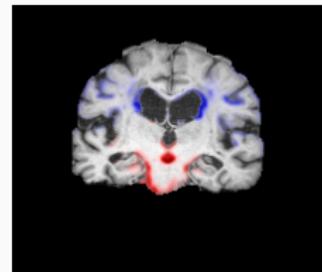
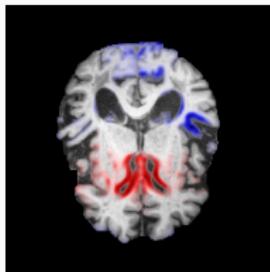
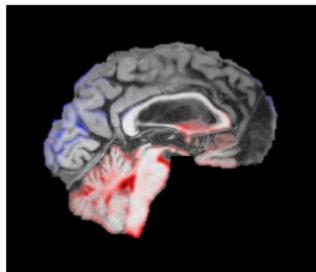
Explainable brain age: Methods



Explainable brain age: Methods



Explainable brain age: Results



Younger
appearing

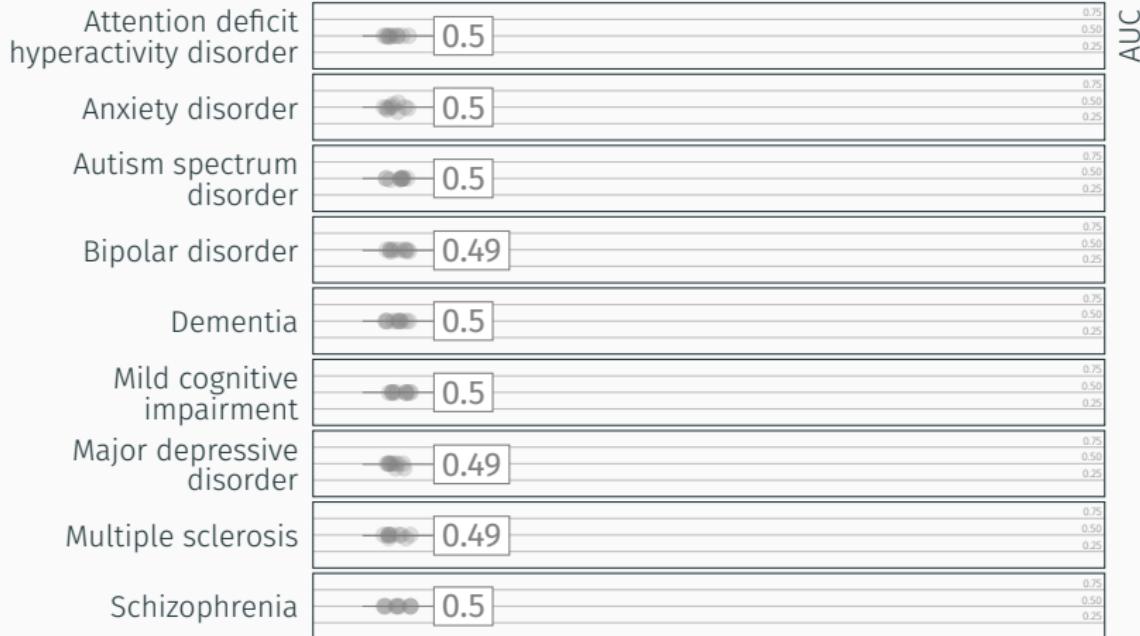
Older
appearing



Explainable brain age: Results



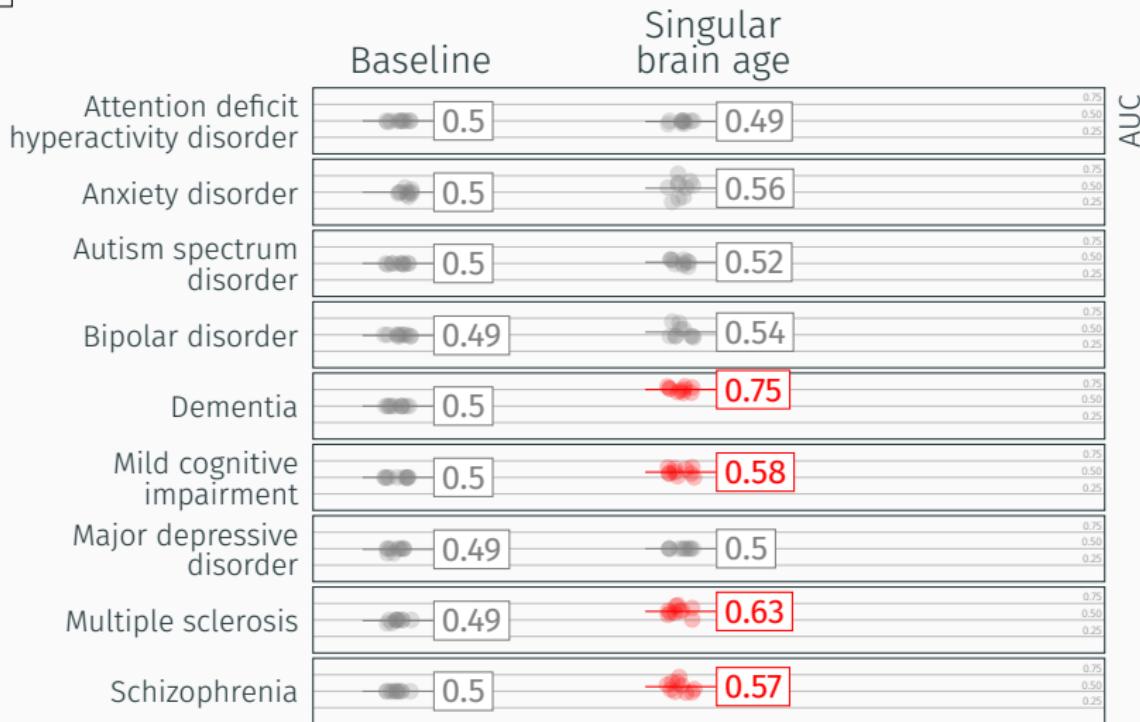
Baseline



AUC



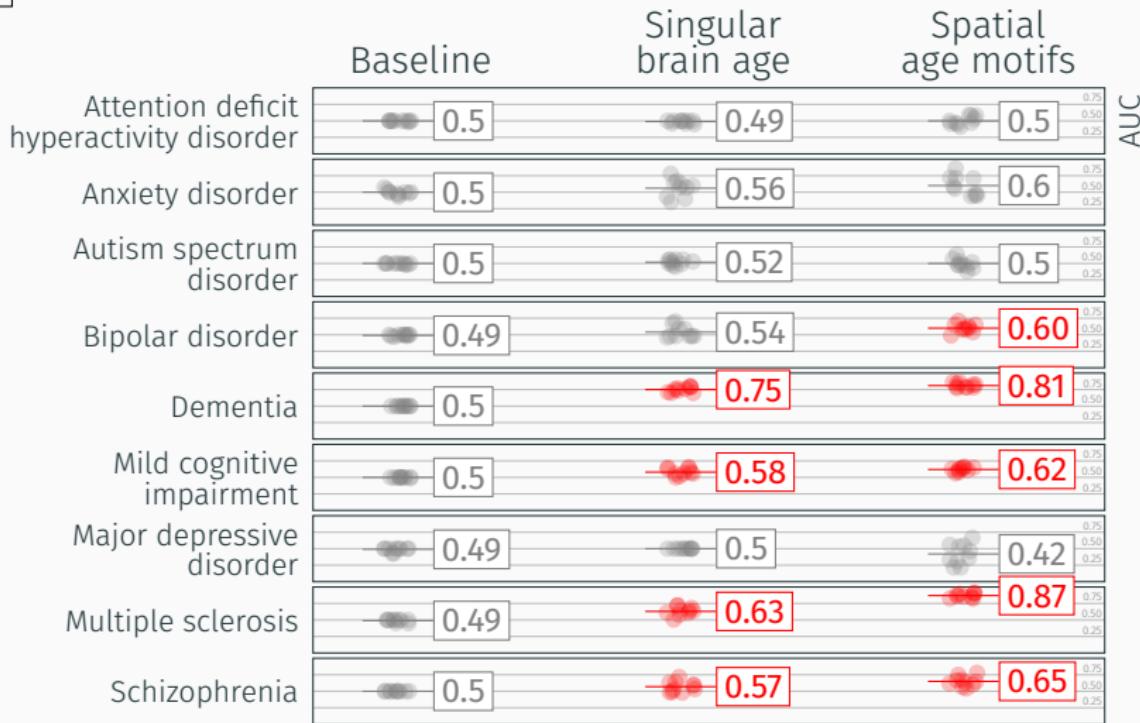
Explainable brain age: Results



AUC



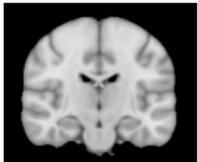
Explainable brain age: Results



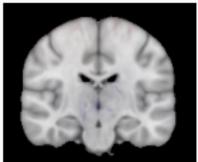
AUC



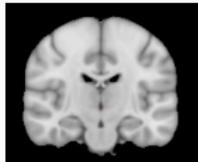
Explainable brain age: Results



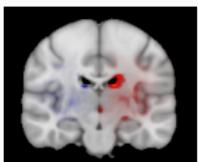
Attention deficit
hyperactivity disorder



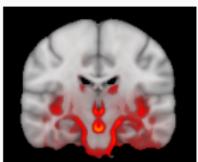
Anxiety
disorder



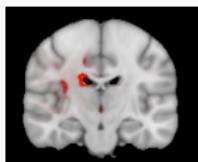
Autism spectrum
disorder



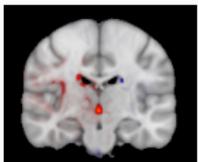
Bipolar
disorder



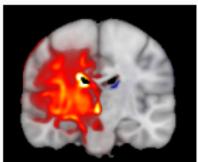
Dementia



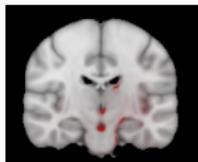
Schizophrenia



Major depressive
disorder



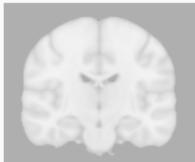
Multiple
sclerosis



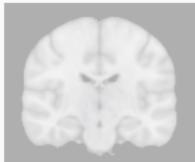
Mild cognitive
impairment



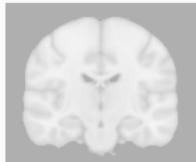
Explainable brain age: Results



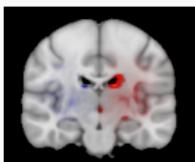
Attention deficit
hyperactivity disorder



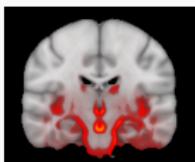
Anxiety
disorder



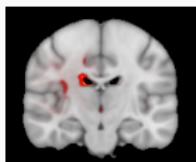
Autism spectrum
disorder



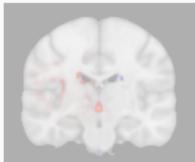
Bipolar
disorder



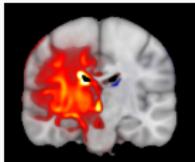
Dementia



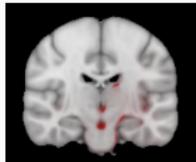
Schizophrenia



Major depressive
disorder



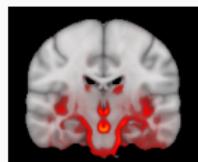
Multiple
sclerosis



Mild cognitive
impairment



Explainable brain age: Results

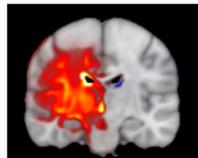


Dementia

- Temporal pole
- Left amygdala
- Parahippocampal gyrus



Explainable brain age: Results

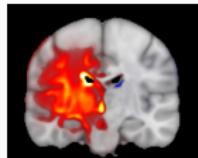


Multiple
sclerosis

- Right pallidum
- Right thalamus
- Right putamen



Explainable brain age: Results

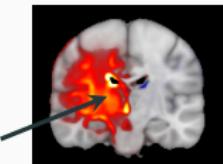


Multiple
sclerosis

- Right pallidum
- Right thalamus
- Right putamen



Explainable brain age: Results

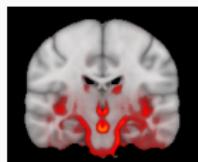


Multiple
sclerosis

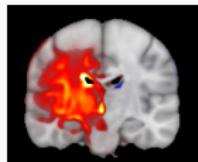
- Right pallidum
- Right thalamus
- Right putamen



Explainable brain age: Results



Dementia



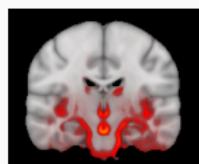
Multiple
sclerosis



Explainable brain age: Results

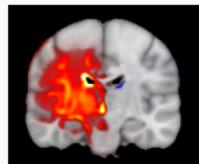


AUC



Dementia

Singular brain age	Spatial age motifs
0.75	0.81



Multiple
sclerosis

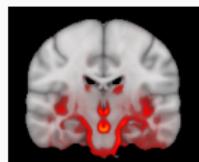
0.63	0.87
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Explainable brain age: Results

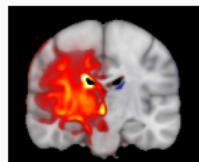


AUC



Singular brain age	Spatial age motifs
0.75	0.06

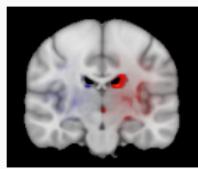
0.75 → 0.81



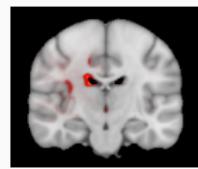
0.63 → 0.87
0.24



Explainable brain age: Results



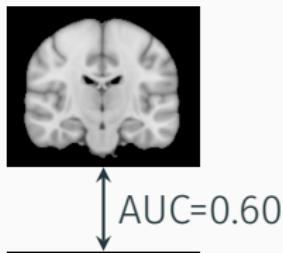
Bipolar
disorder



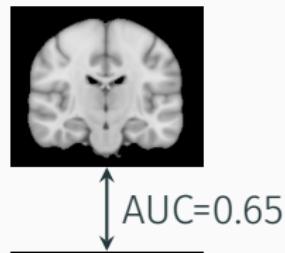
Schizophrenia



Explainable brain age: Results



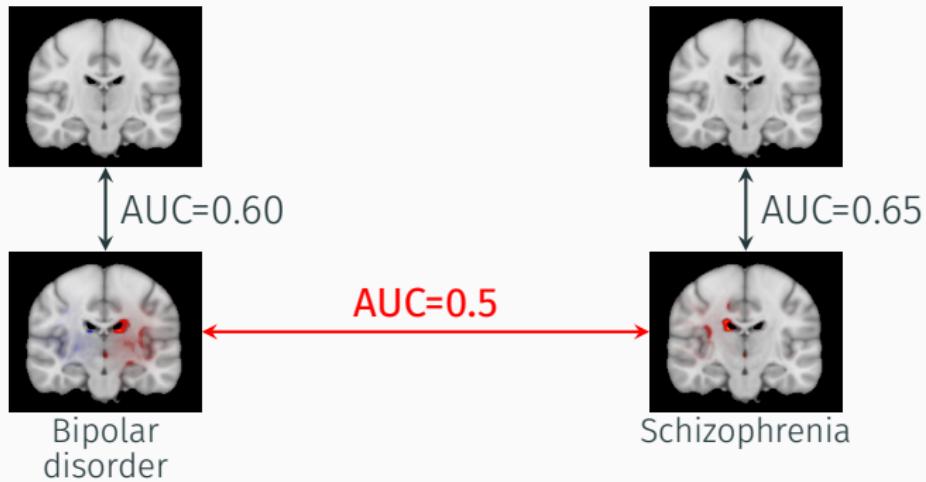
Bipolar
disorder



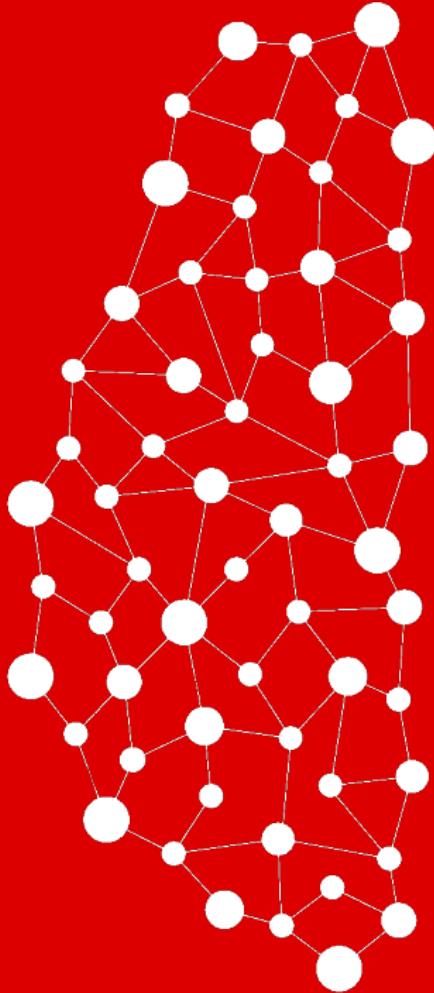
Schizophrenia



Explainable brain age: Results



Thank you for your attention!
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