

# Exploring brain heterogeneity in neuropsychiatric patients with explainable artificial intelligence



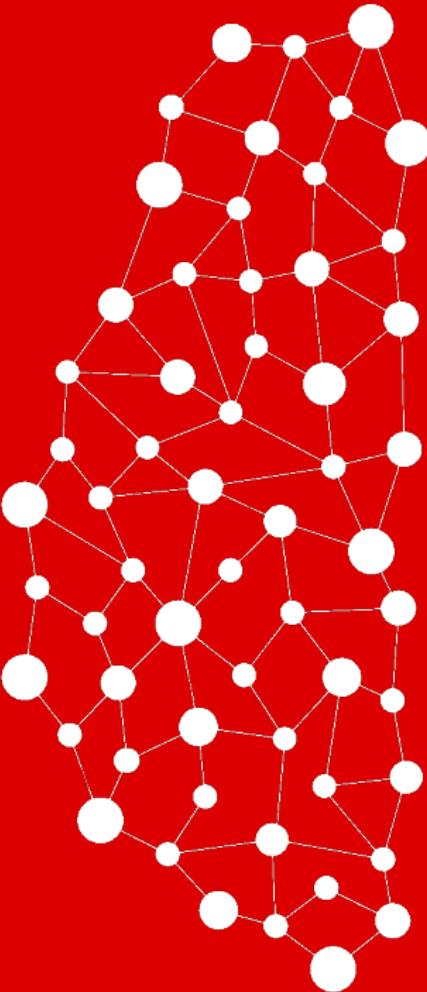
Esten H. Leonardsen

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

Chief Scientific Officer, baba.vision



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# Outline

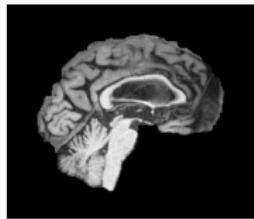
1. Background
2. Explainable artificial intelligence for dementia-prediction
3. Explainable brain age predictions



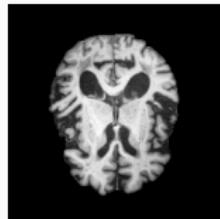
# Background: Predictive clinical neuroscience



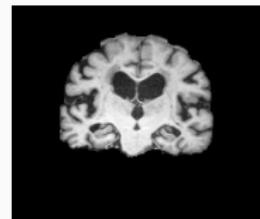
# Background: Predictive clinical neuroscience



Side

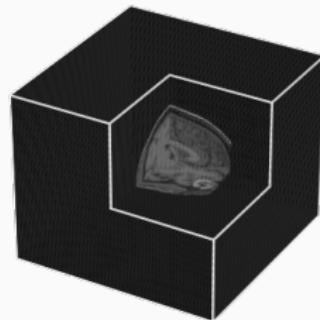


Above



Front

Structural Magnetic  
Resonance Imaging (MRI) scans



# Background: Predictive clinical neuroscience



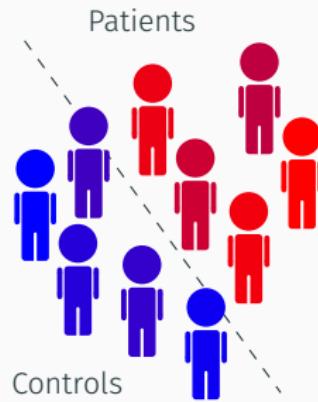
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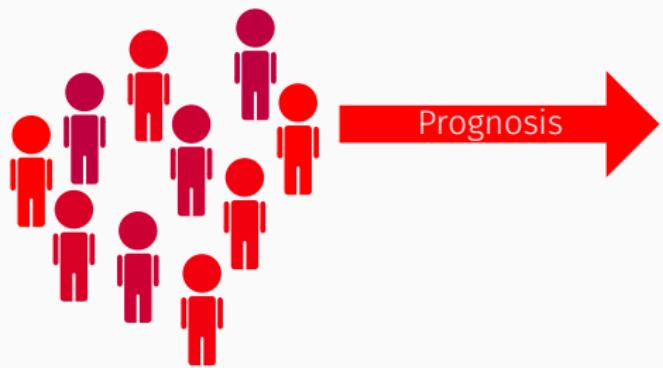
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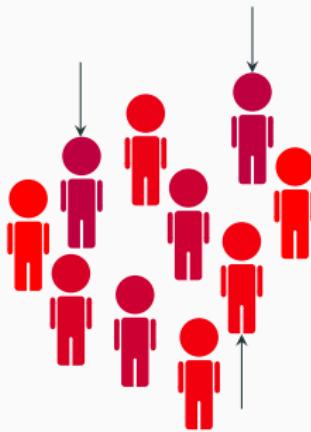
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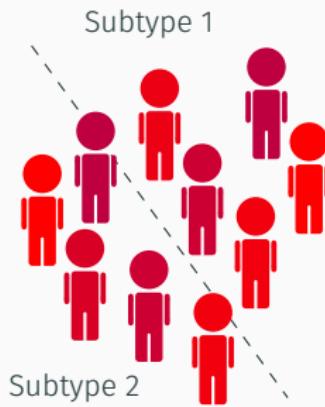
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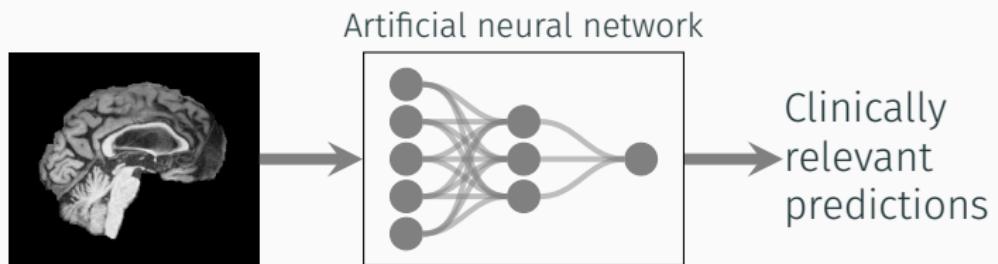
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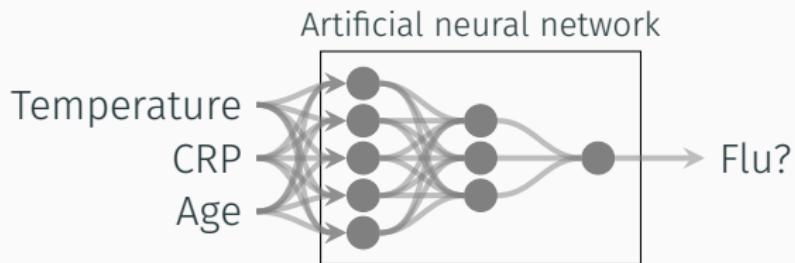
# Background: Explainable artificial intelligence



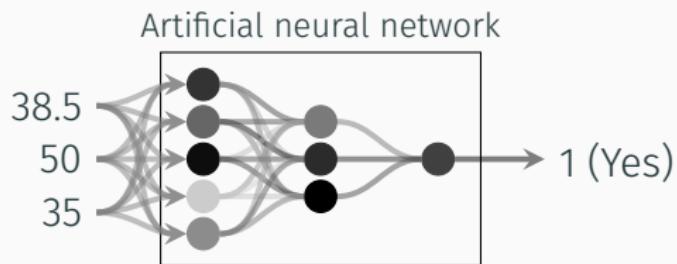
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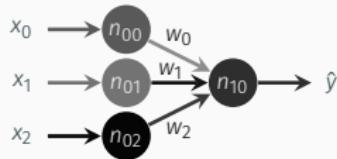
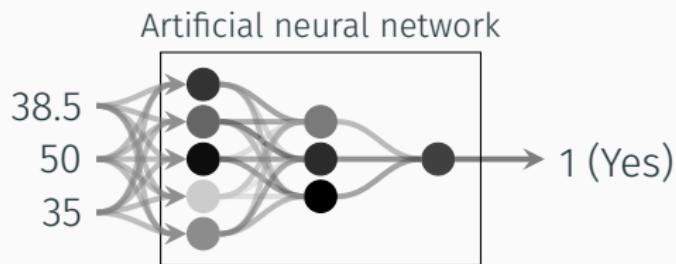
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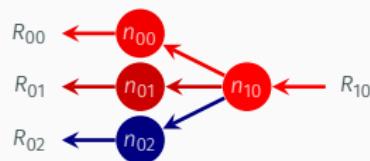
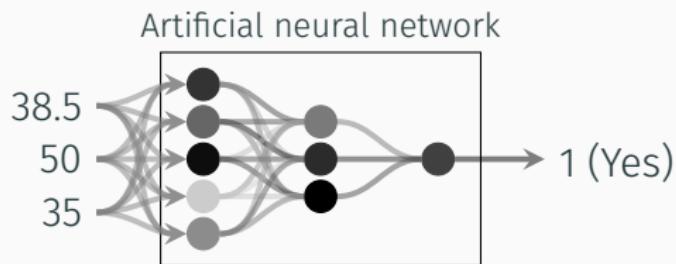


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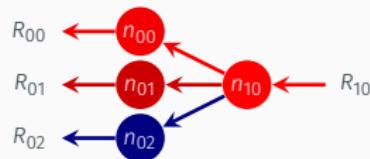
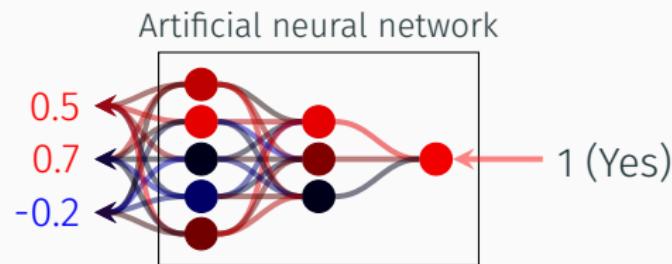
$$\hat{y} = f \left( \sum_i^N w_i \cdot n_{0i} \right)$$

# Background: Explainable artificial intelligence



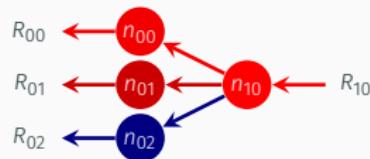
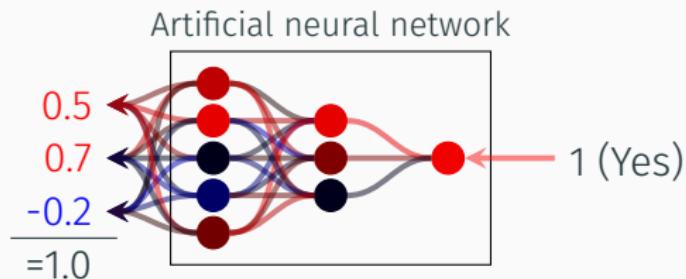
$$R_{0i} = \sum_j \frac{n_{0i} w_i}{\sum_k n_{0k} w_k} R_{1j}$$

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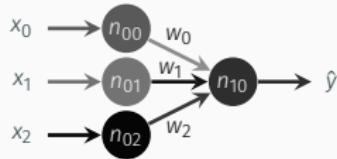
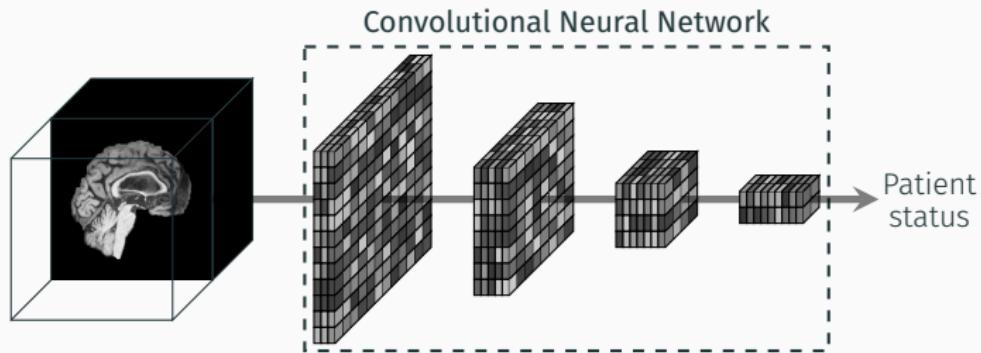
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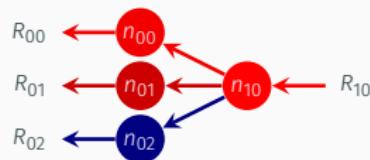
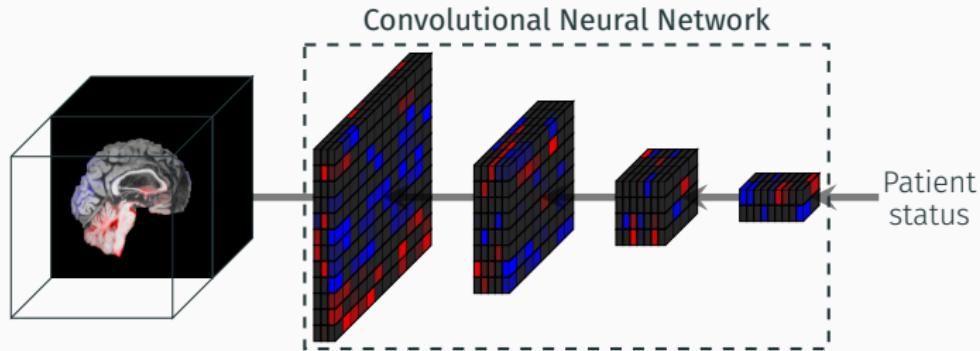
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$$\hat{y} = f \left( \sum_i^N w_i \cdot n_{0i} \right)$$



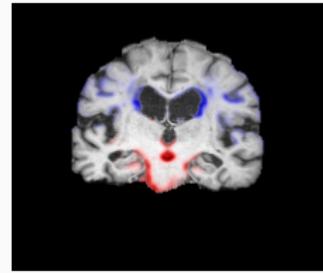
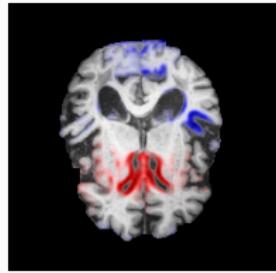
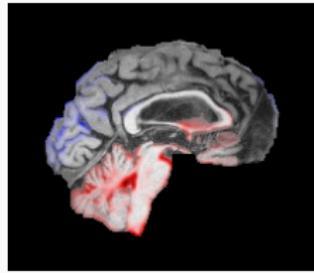
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# Background: Explainable artificial intelligence



# 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



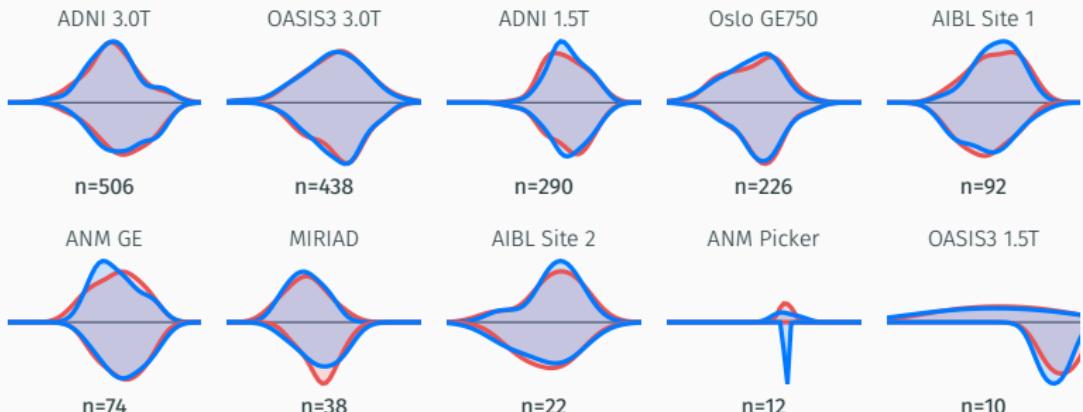
FEMALE

MALE

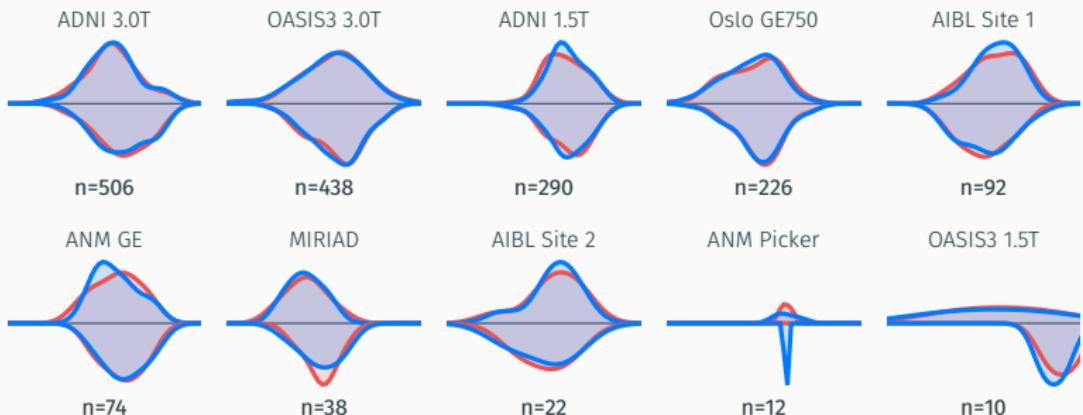
55 60 65 70 75 80 85 90 95

n=1708

?? Controls  
?? Patients



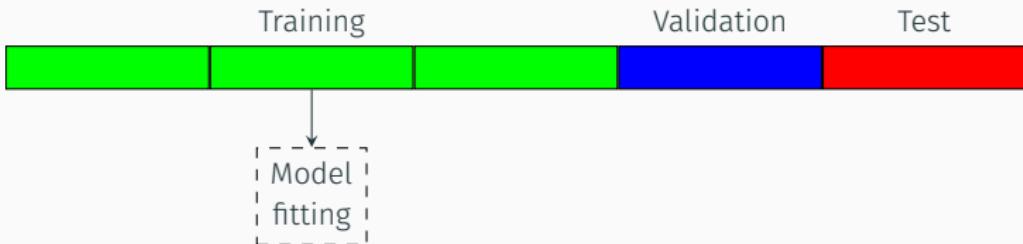
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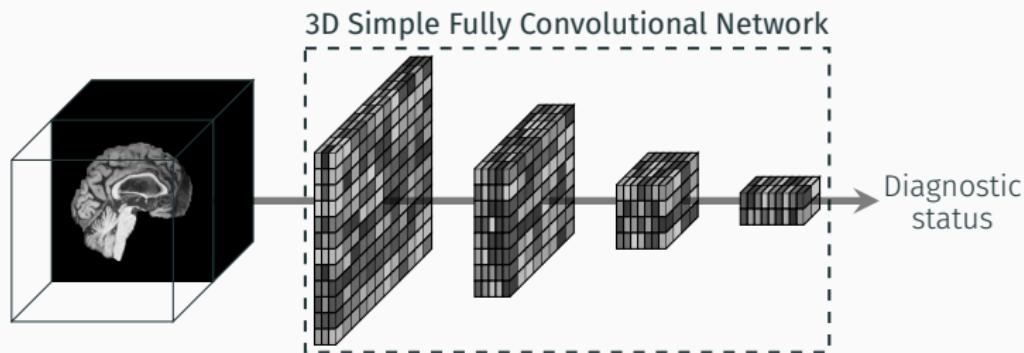
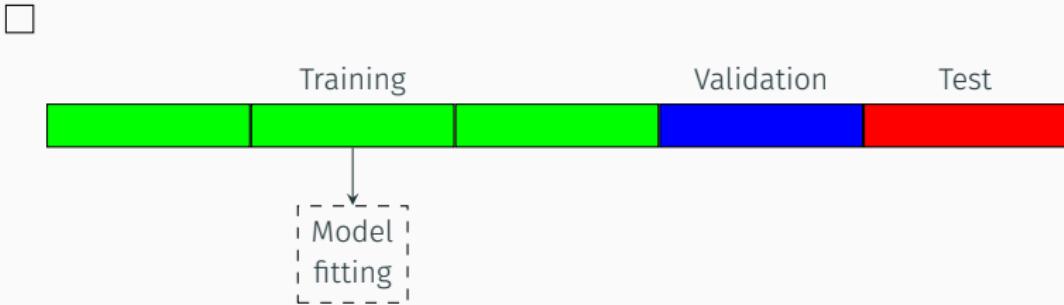
## Explainability and dementia: Modelling



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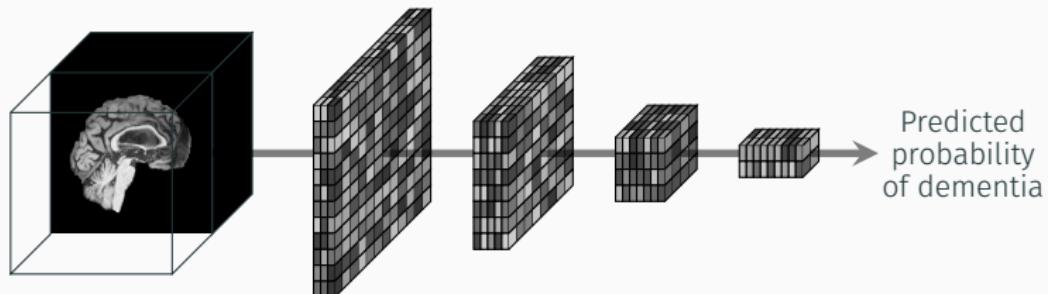
# Explainability and dementia: Modelling



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



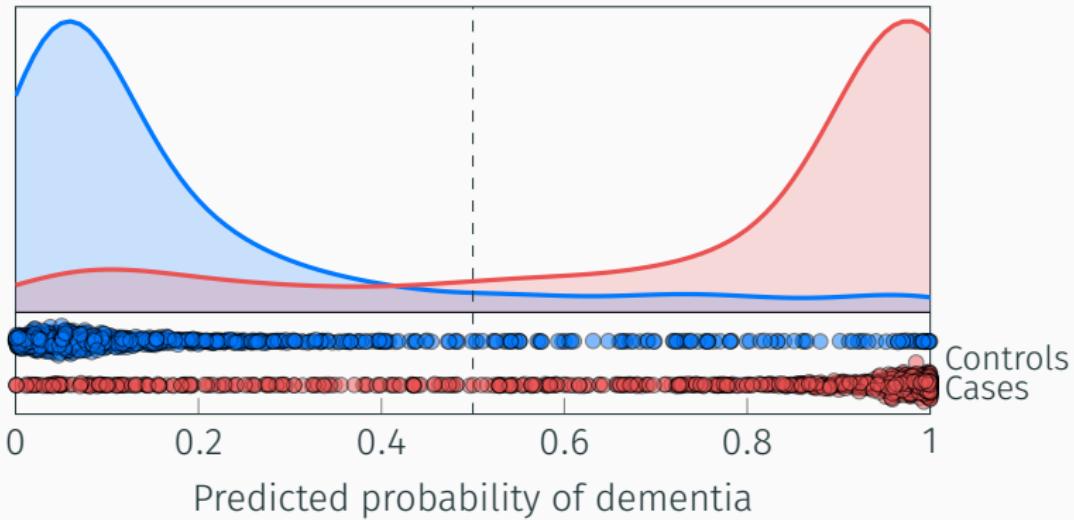
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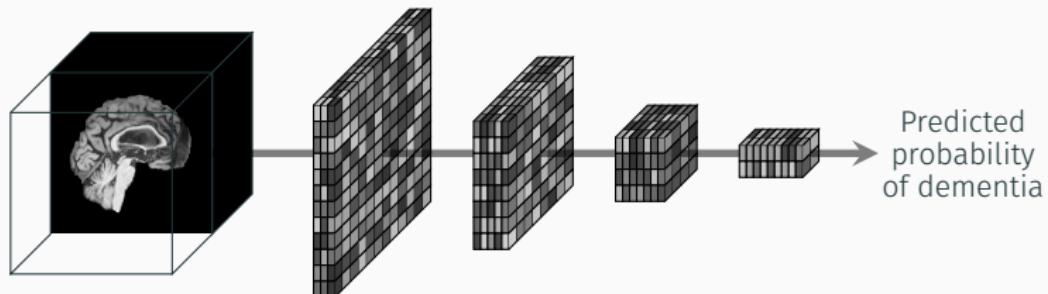


# Explainability and dementia: Modelling

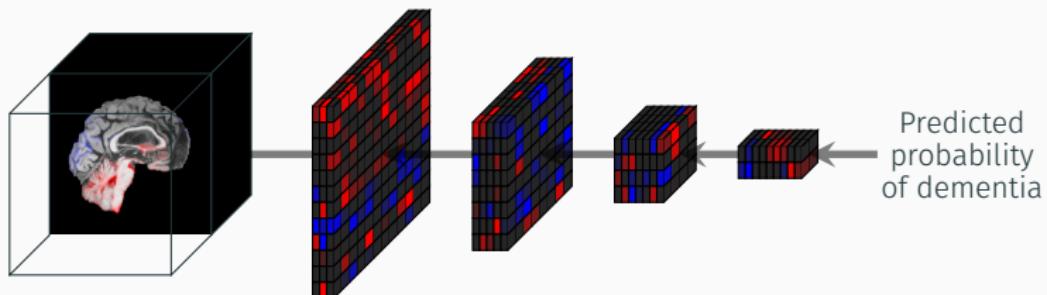


AUC=0.91, balanced accuracy=85%

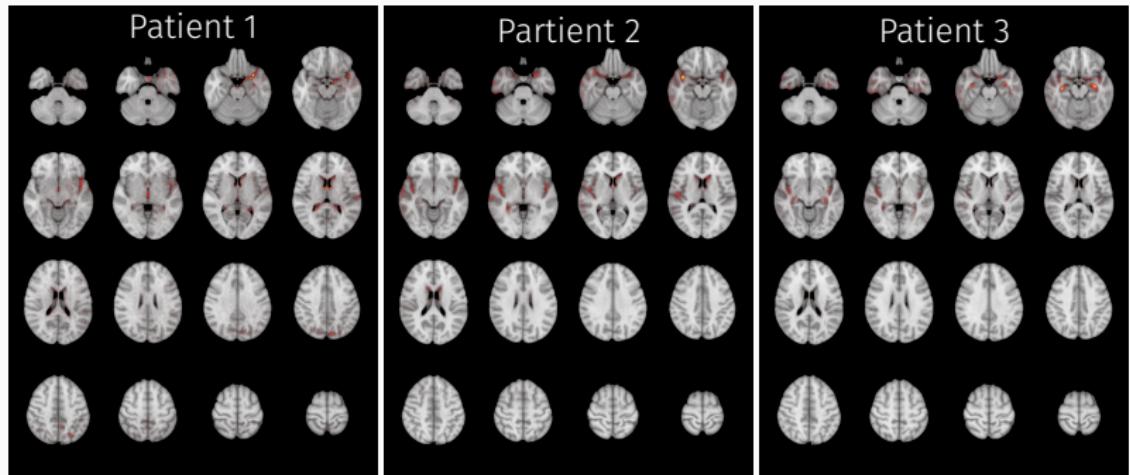
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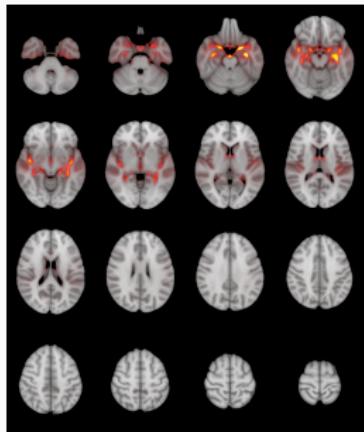
# Explainability and dementia: Validation



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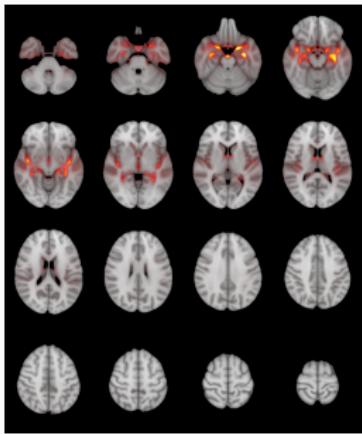
LRP



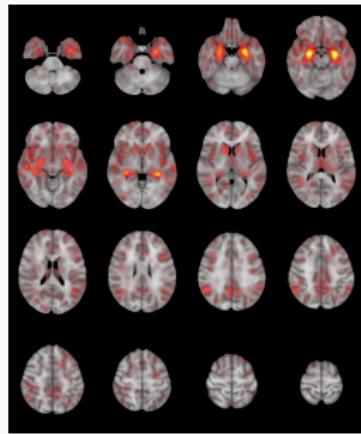
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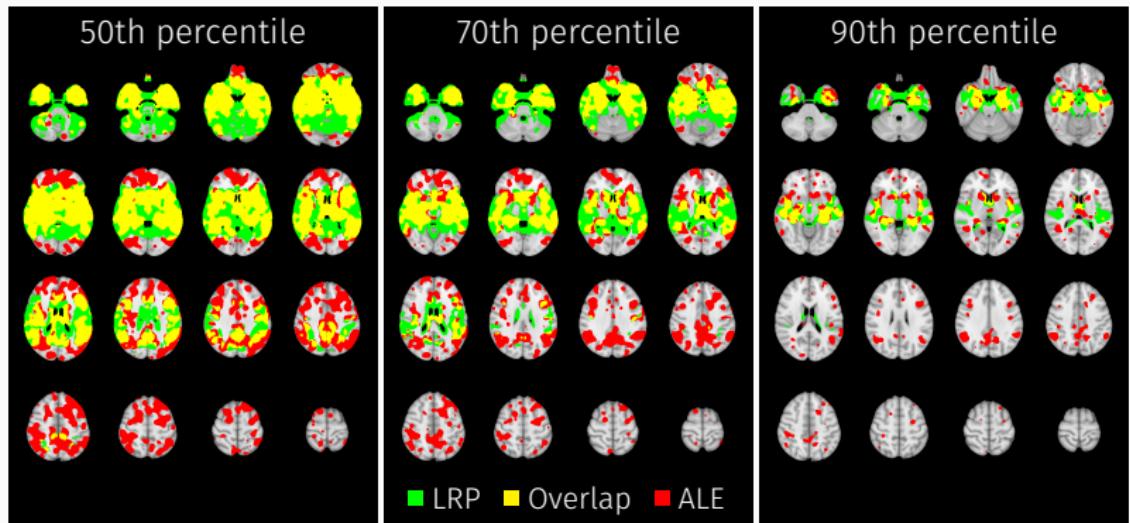
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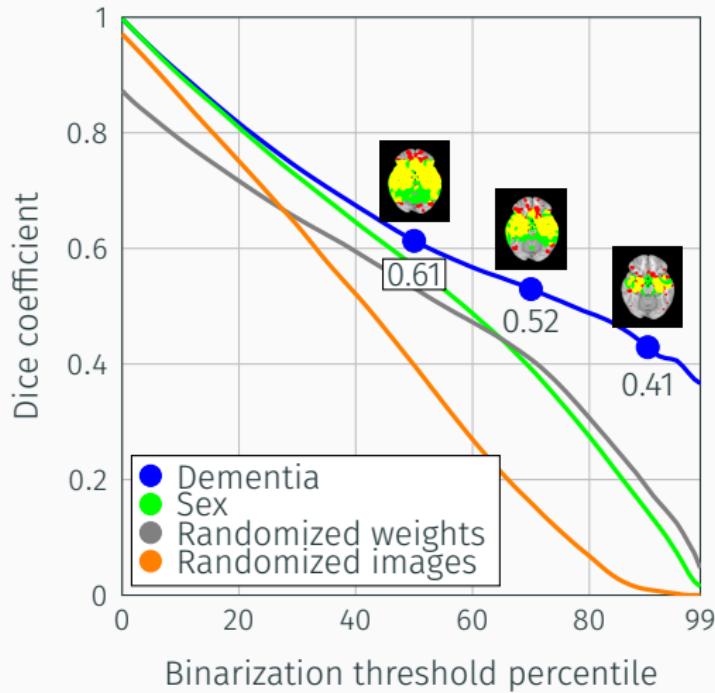
GingerALE



# Explainability and dementia: Validation



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# Explainability and dementia: Validation



AOPC



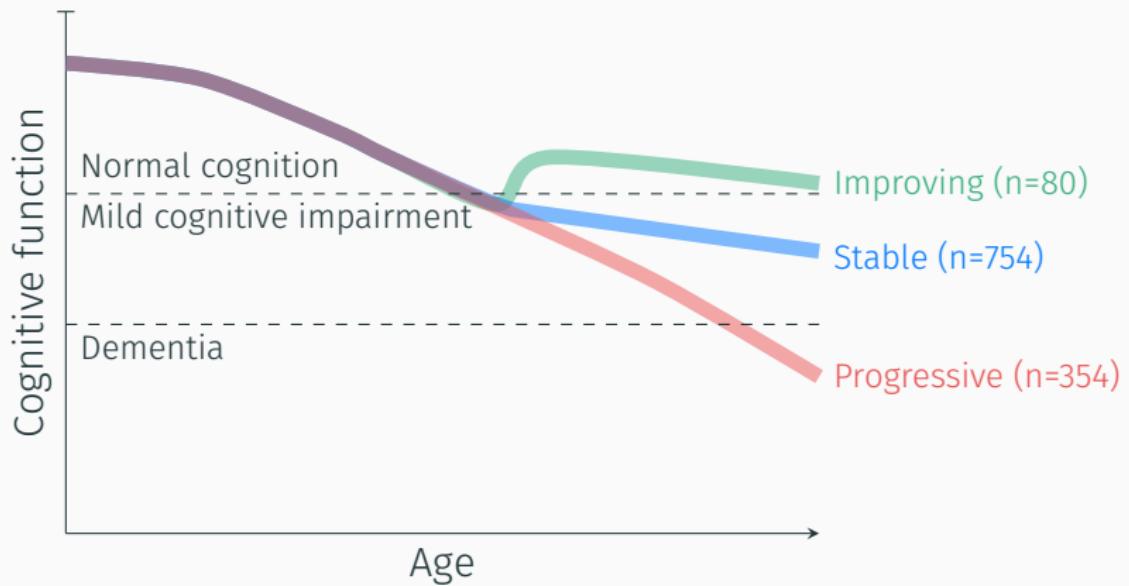
# Explainability and dementia: Application



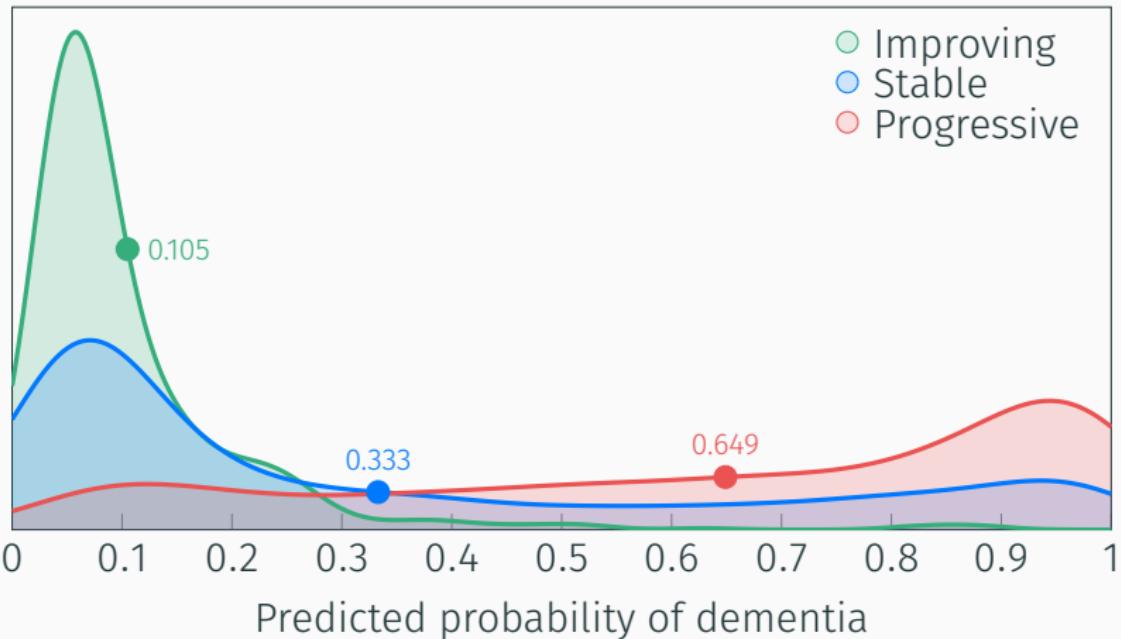
MCI dataset



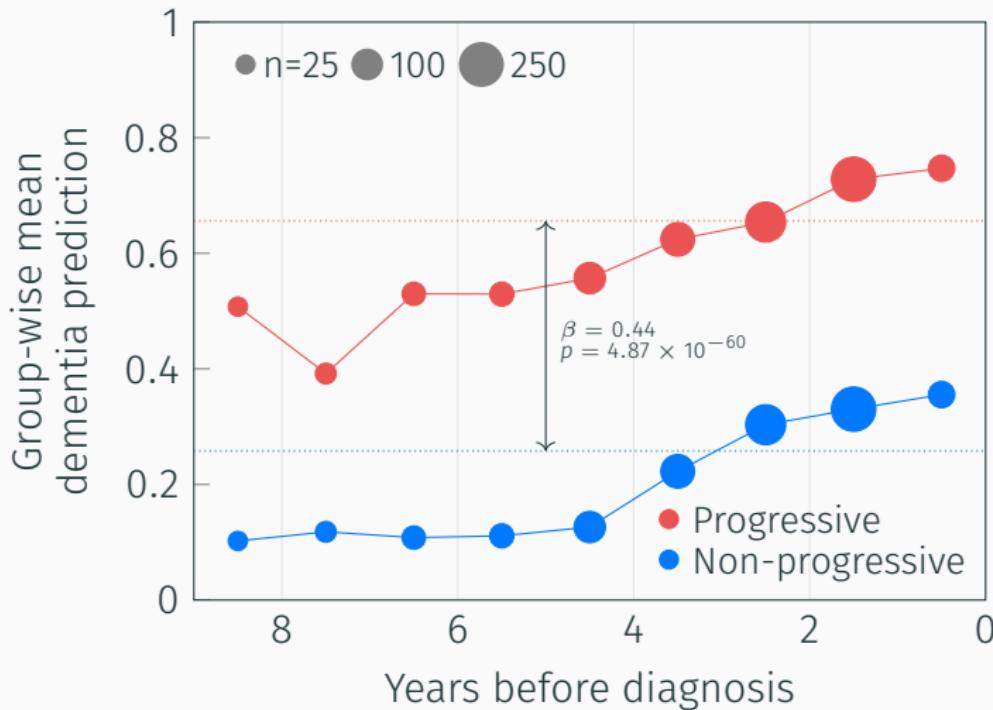
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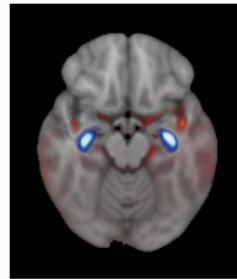
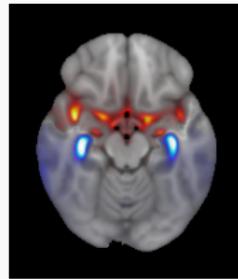
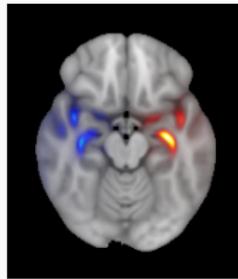
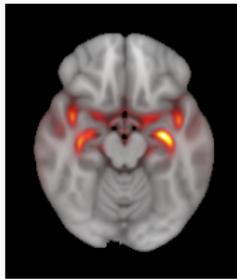
# Explainability and dementia: Application



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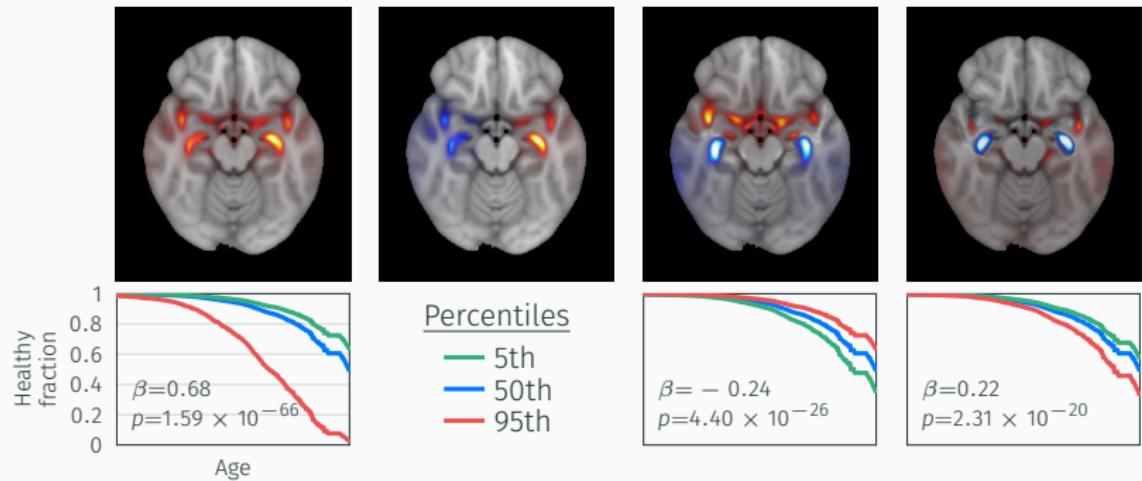
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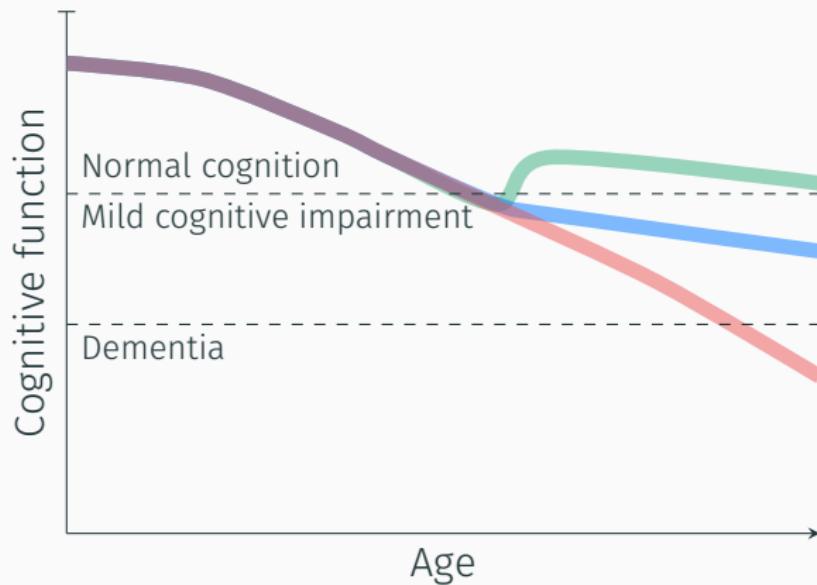
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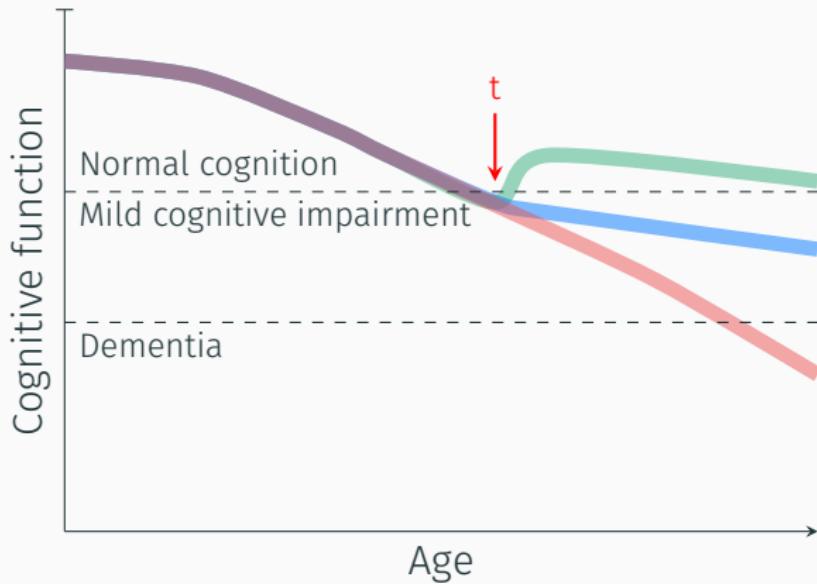
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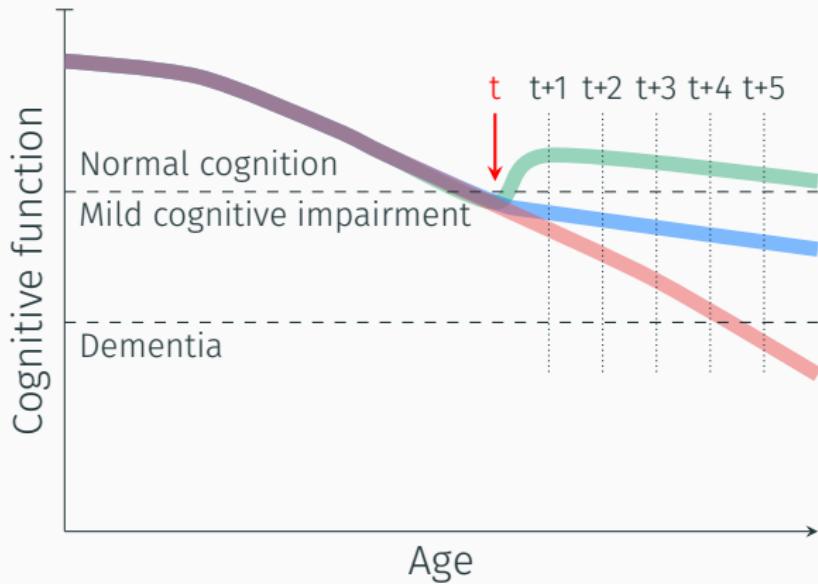
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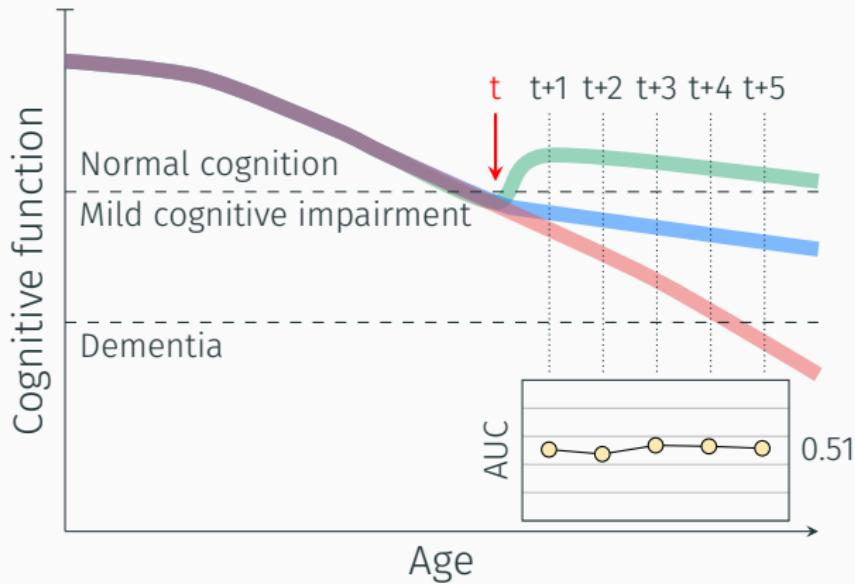
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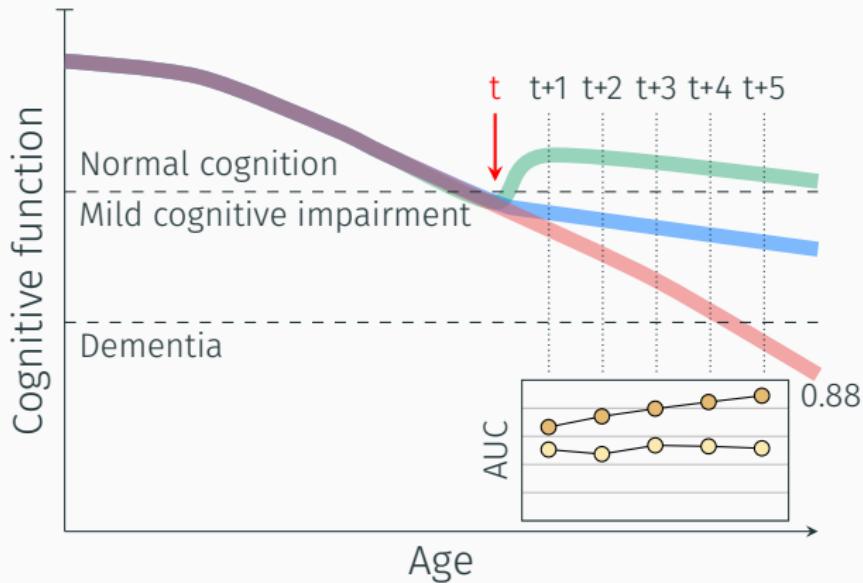
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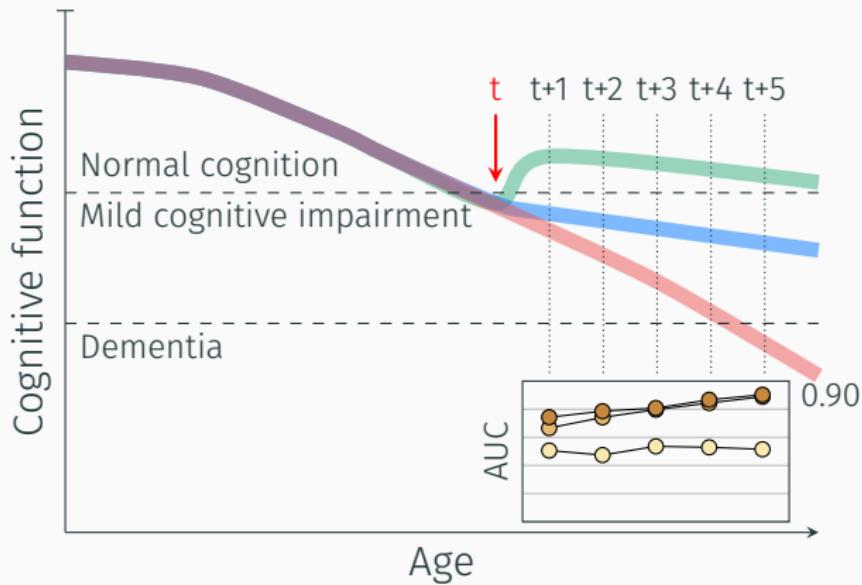
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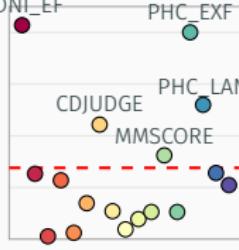
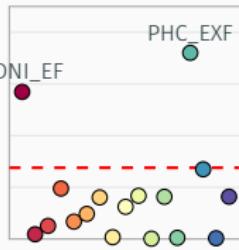
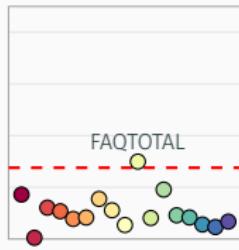
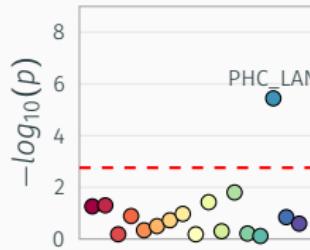
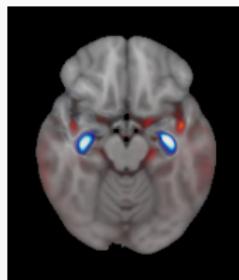
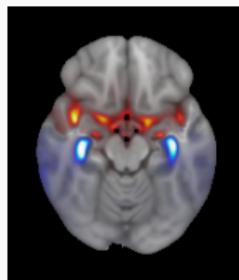
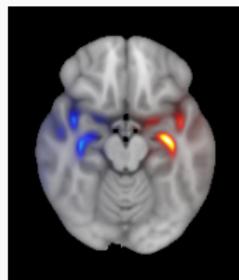
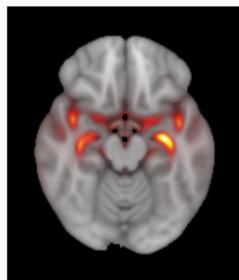
# Explainability and dementia: Application



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# Explainability and dementia: Application



Morphological record



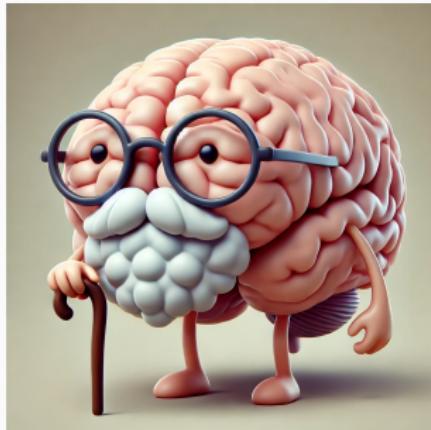
# Explainable brain age

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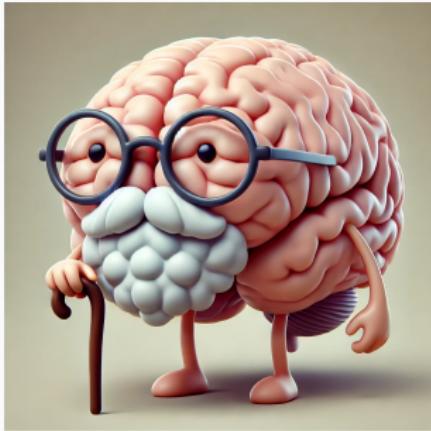
# Explainable brain age: Motivation



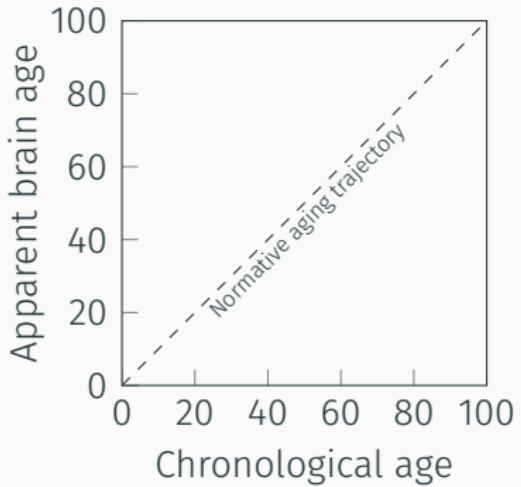
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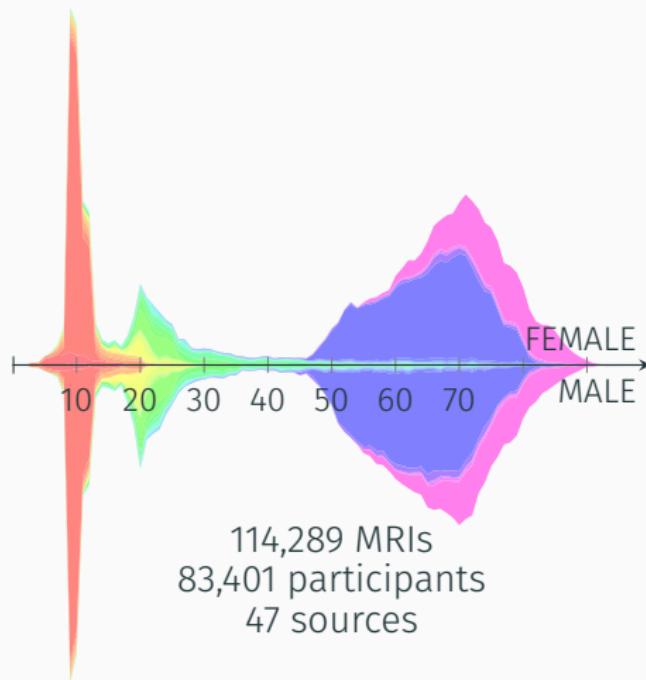
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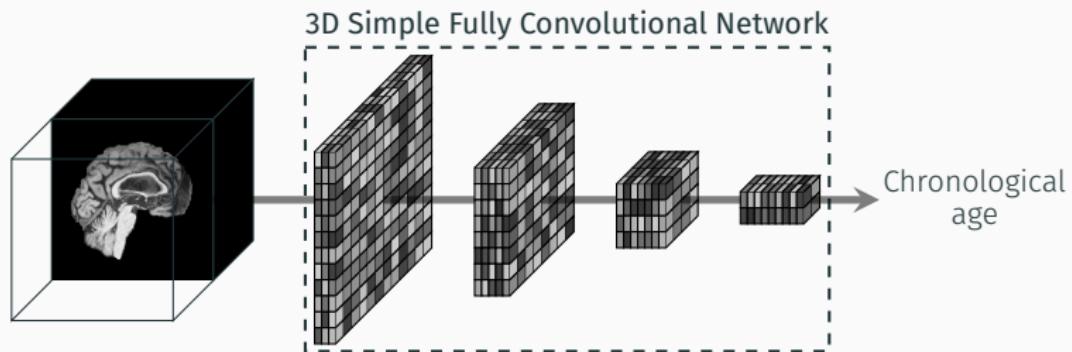
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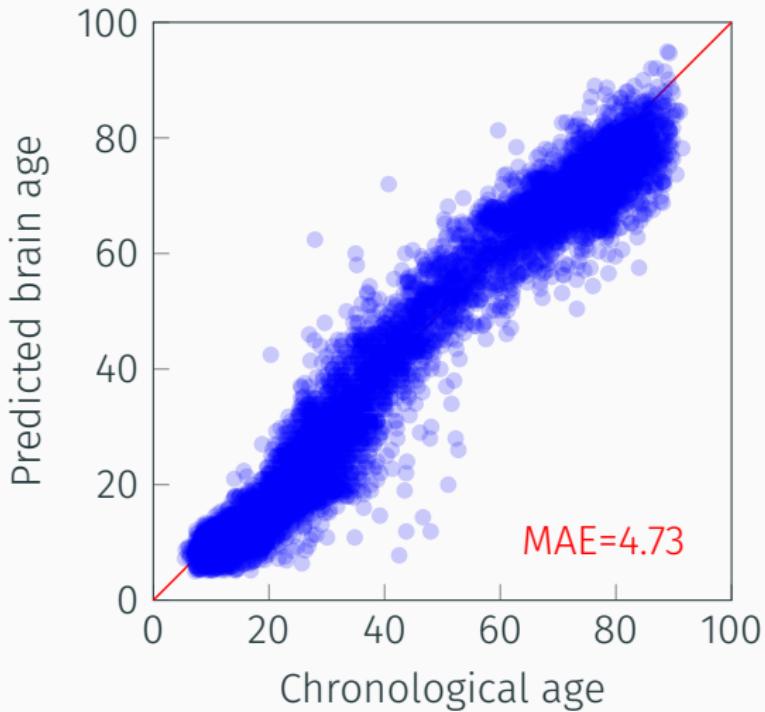
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- NIMH
- HBN
- NKI-RS
- ABCD
- MPI-LEMON
- QTAB
- ds003592
- PING
- ds004302
- ADHD200
- SALD
- PNC
- ABIDE-II
- ds000119
- ABIDE-I
- BRAINMINT
- SLIM
- QTIM
- Beijing
- PPMI
- AOMIC-PIOP2
- UKBB
- ds000222
- IXI
- DLBS
- Cam-CAN
- StrokeMRI
- Tao-Wu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



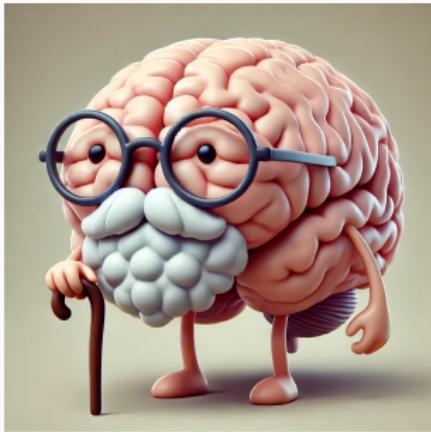
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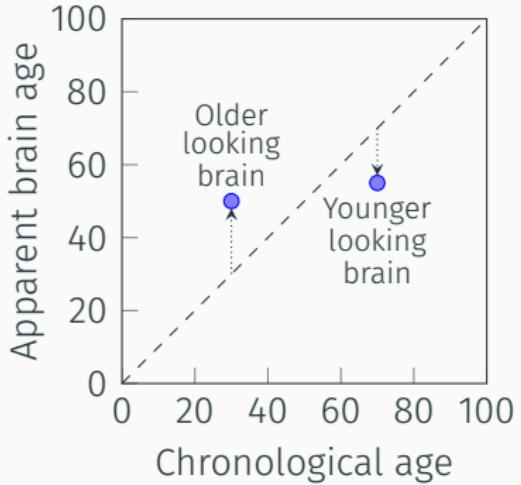
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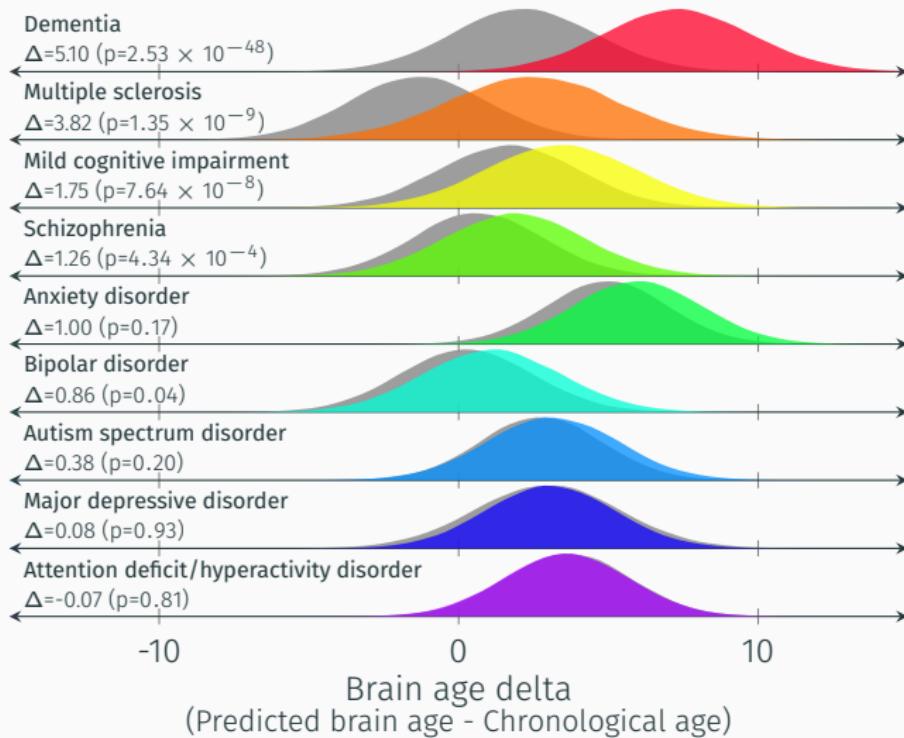
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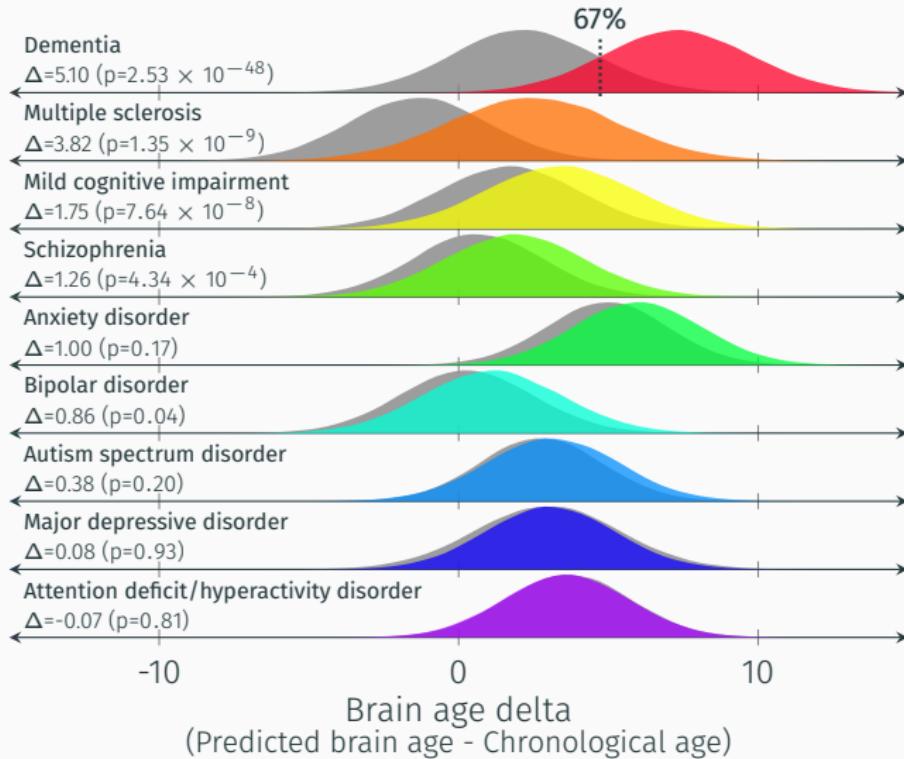
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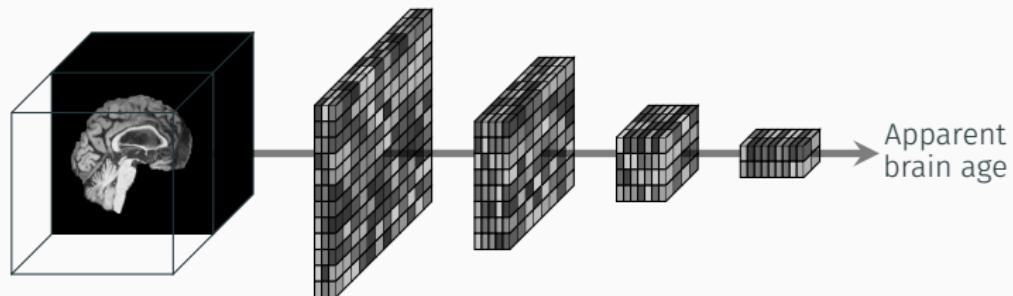
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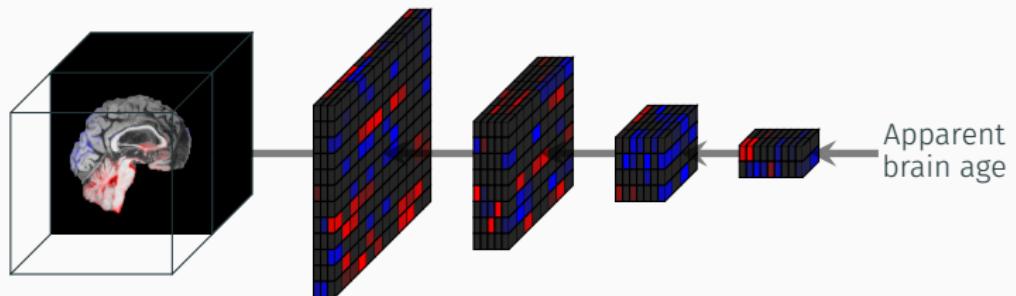
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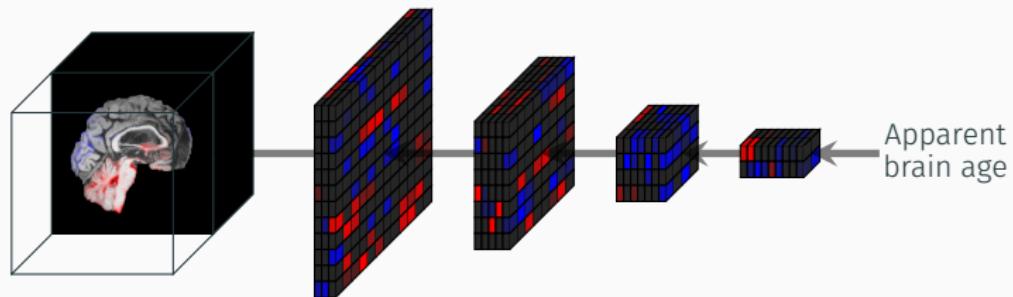
# Explainable brain age: Methods



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Filters



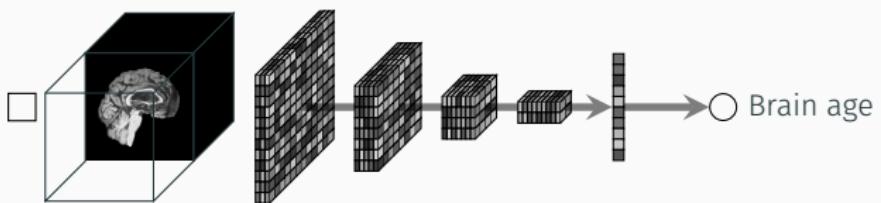
# Explainable brain age: Methods



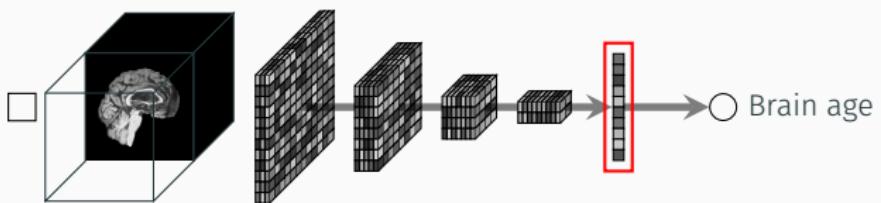
Feature correlation



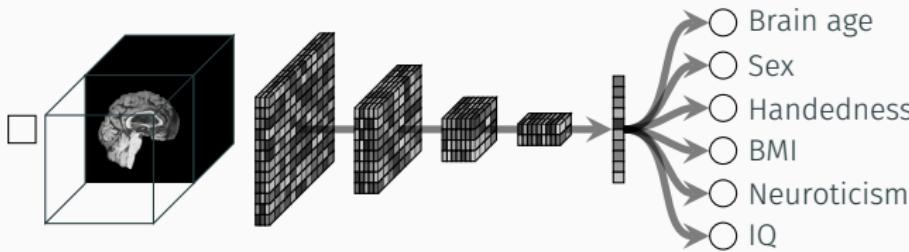
# Explainable brain age: Methods



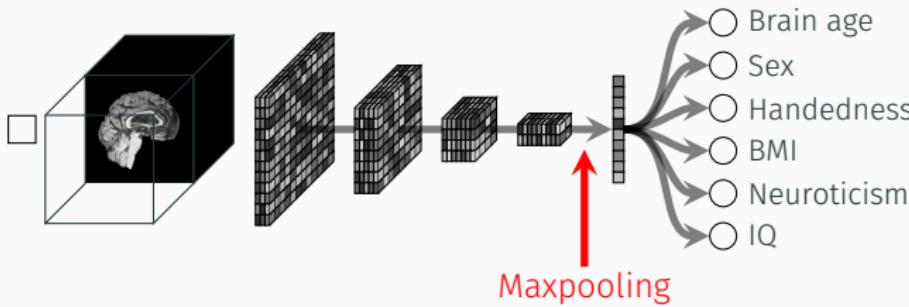
# Explainable brain age: Methods



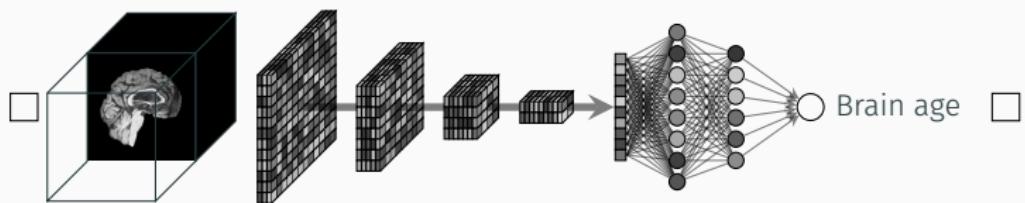
# Explainable brain age: Methods



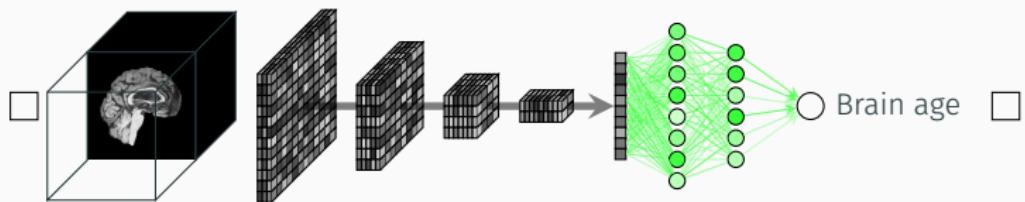
# Explainable brain age: Methods



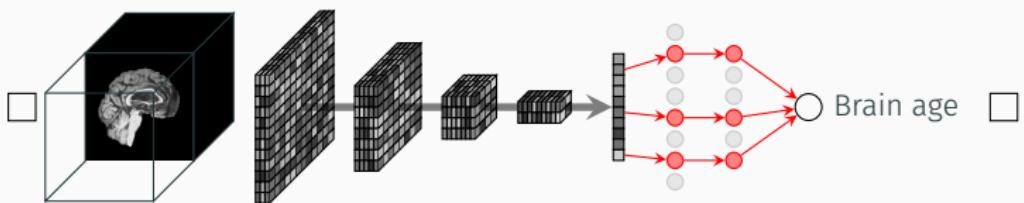
# Explainable brain age: Methods



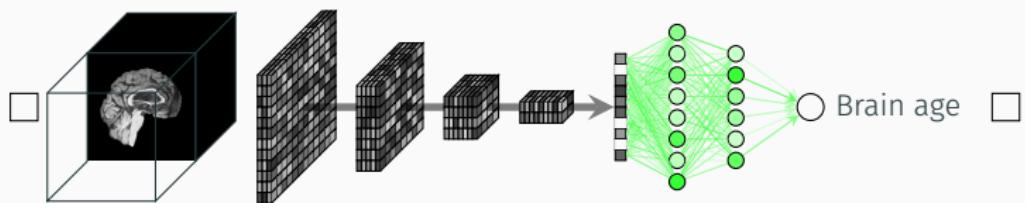
# Explainable brain age: Methods



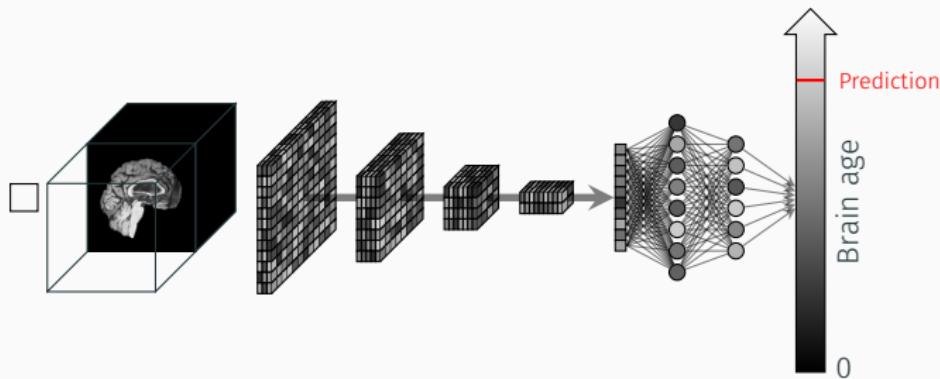
# Explainable brain age: Methods



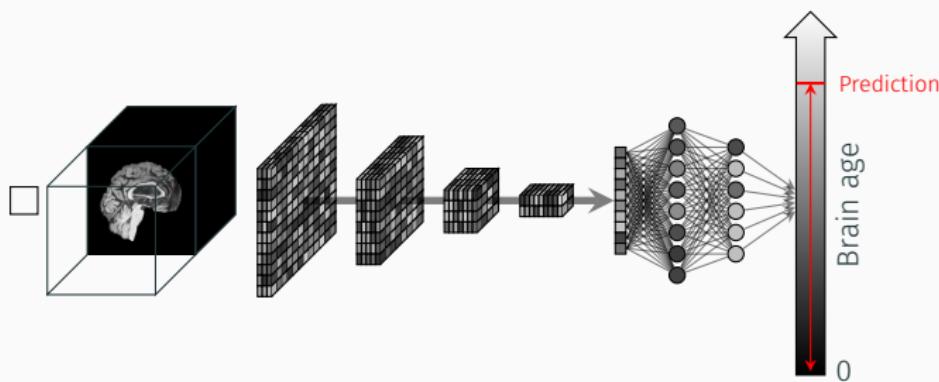
# Explainable brain age: Methods



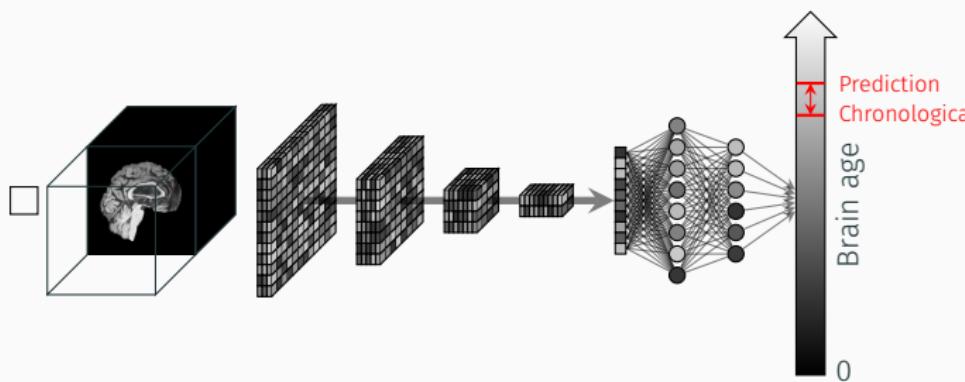
# Explainable brain age: Methods



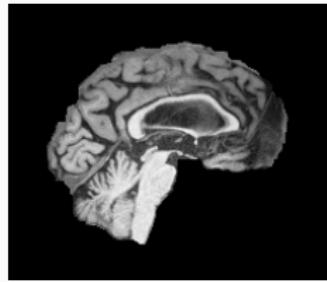
# Explainable brain age: Methods



# Explainable brain age: Methods



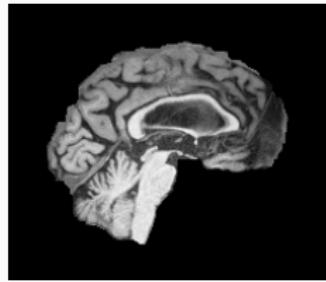
# Explainable brain age: Methods



Age  
62



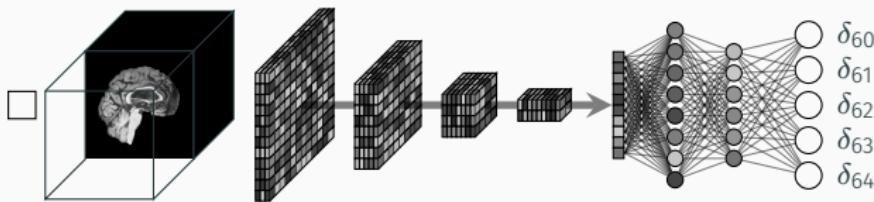
# Explainable brain age: Methods



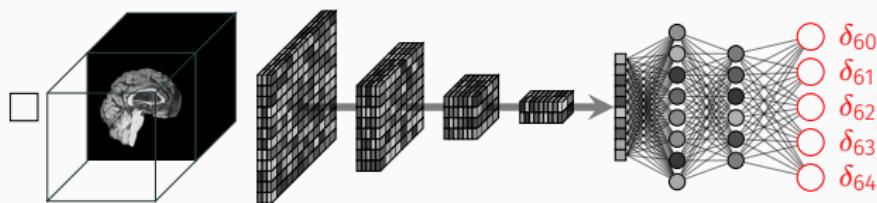
$\delta_{60}$	$\delta_{61}$	$\delta_{62}$	$\delta_{63}$	$\delta_{64}$
2	1	0	-1	-2



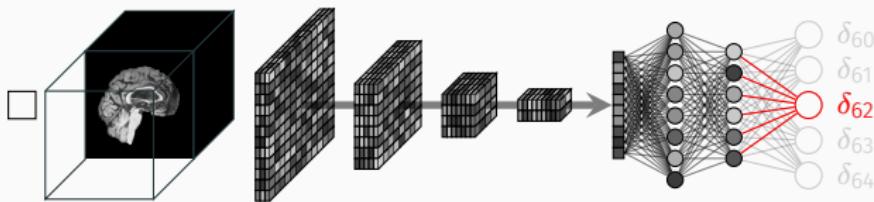
# Explainable brain age: Methods



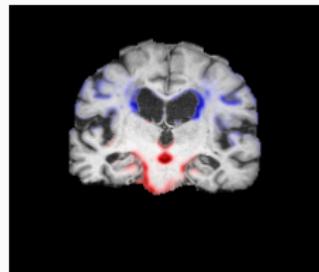
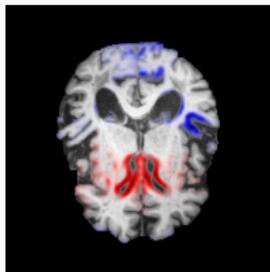
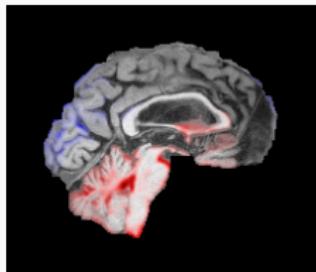
# Explainable brain age: Methods



# Explainable brain age: Methods



# Explainable brain age: Results



Younger  
appearing

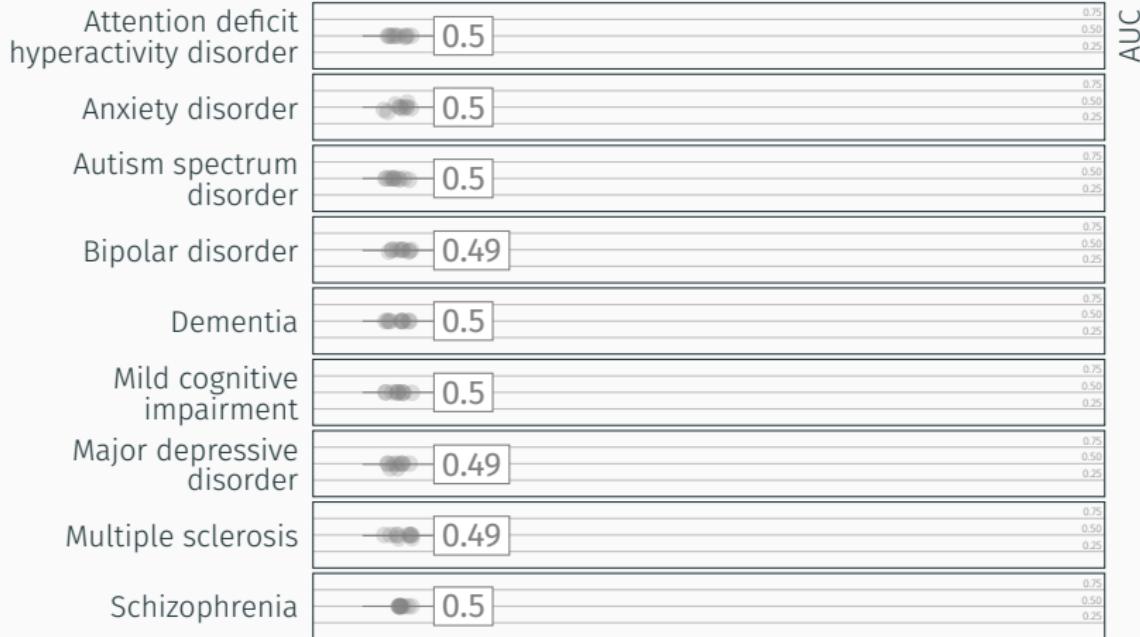
Older  
appearing



# Explainable brain age: Results



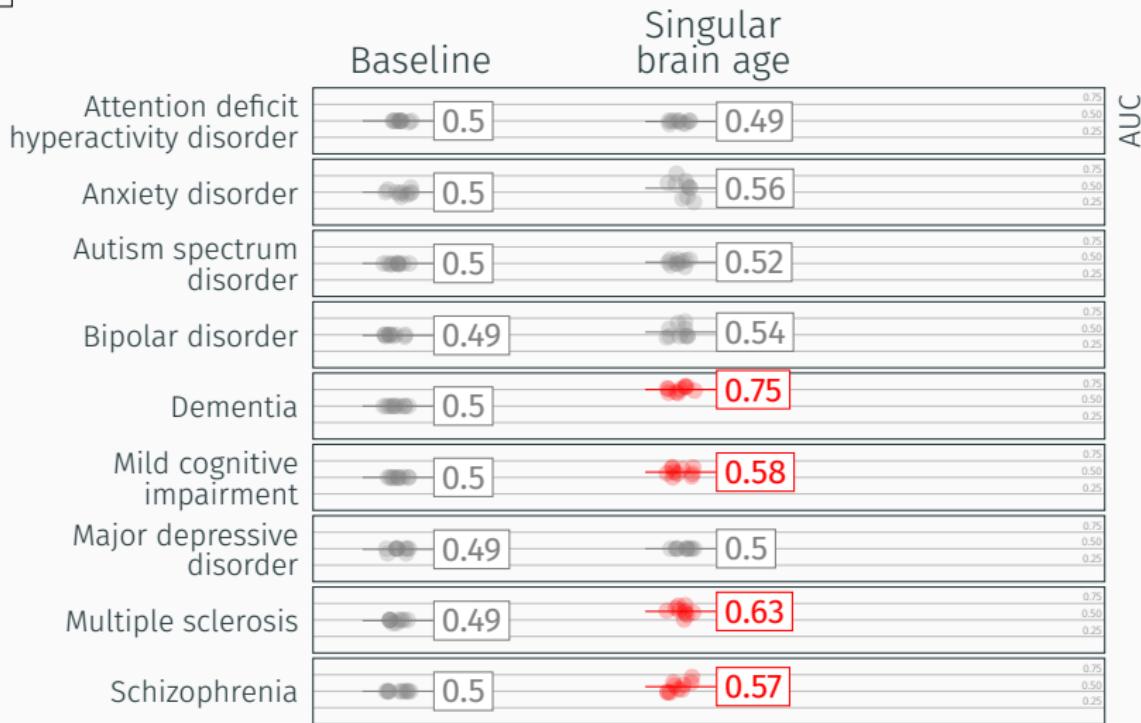
Baseline



AUC



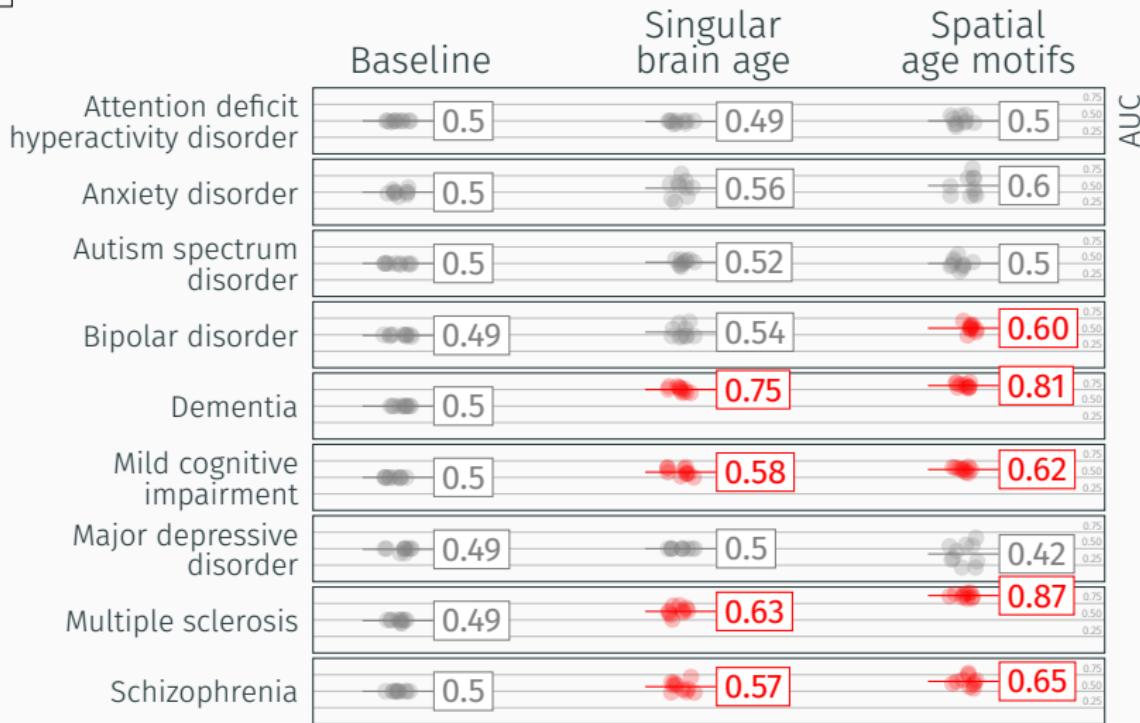
# Explainable brain age: Results



AUC



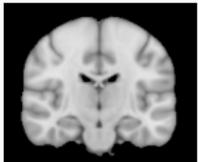
# Explainable brain age: Results



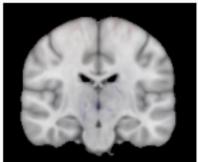
AUC



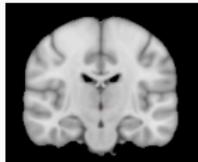
# Explainable brain age: Results



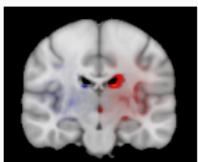
Attention deficit  
hyperactivity disorder



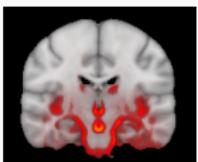
Anxiety  
disorder



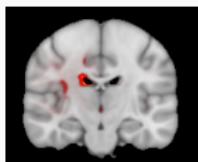
Autism spectrum  
disorder



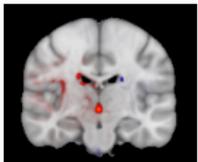
Bipolar  
disorder



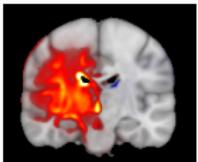
Dementia



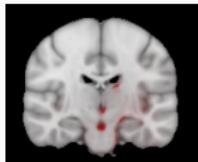
Schizophrenia



Major depressive  
disorder



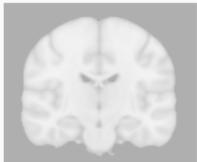
Multiple  
sclerosis



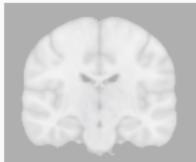
Mild cognitive  
impairment



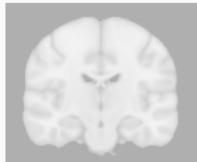
# Explainable brain age: Results



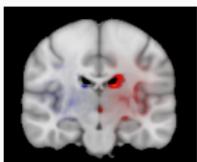
Attention deficit  
hyperactivity disorder



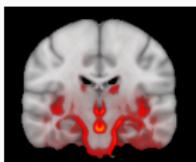
Anxiety  
disorder



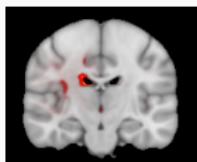
Autism spectrum  
disorder



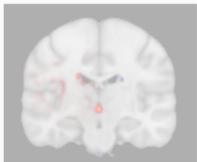
Bipolar  
disorder



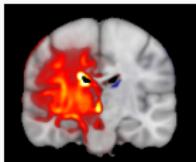
Dementia



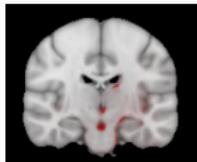
Schizophrenia



Major depressive  
disorder



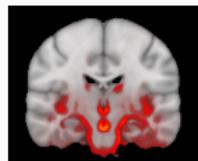
Multiple  
sclerosis



Mild cognitive  
impairment



# Explainable brain age: Results

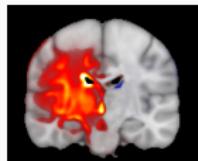


Dementia

- Temporal pole
- Left amygdala
- Parahippocampal gyrus



# Explainable brain age: Results

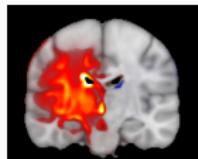


Multiple  
sclerosis

- Right pallidum
- Right thalamus
- Right putamen



# Explainable brain age: Results

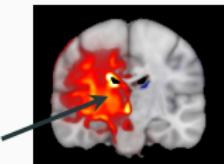


Multiple  
sclerosis

- Right pallidum
- Right thalamus
- Right putamen



# Explainable brain age: Results

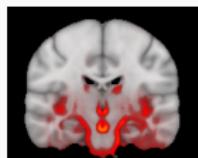


Multiple  
sclerosis

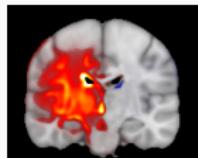
- Right pallidum
- Right thalamus
- Right putamen



# Explainable brain age: Results



Dementia



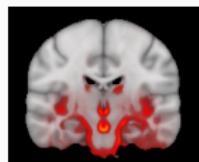
Multiple  
sclerosis



# Explainable brain age: Results

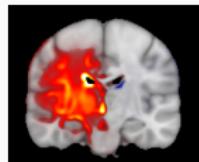


AUC



Dementia

Singular brain age	Spatial age motifs
0.75	0.81



Multiple  
sclerosis

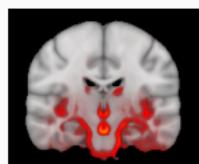
0.63	0.87
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# Explainable brain age: Results

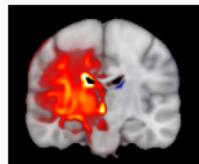


AUC



Singular brain age	Spatial age motifs
0.75	0.06

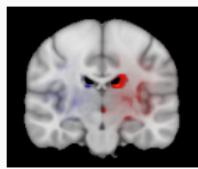
0.75 → 0.81



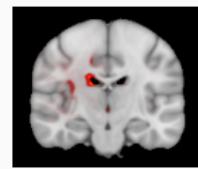
0.63 → 0.87  
0.24



# Explainable brain age: Results



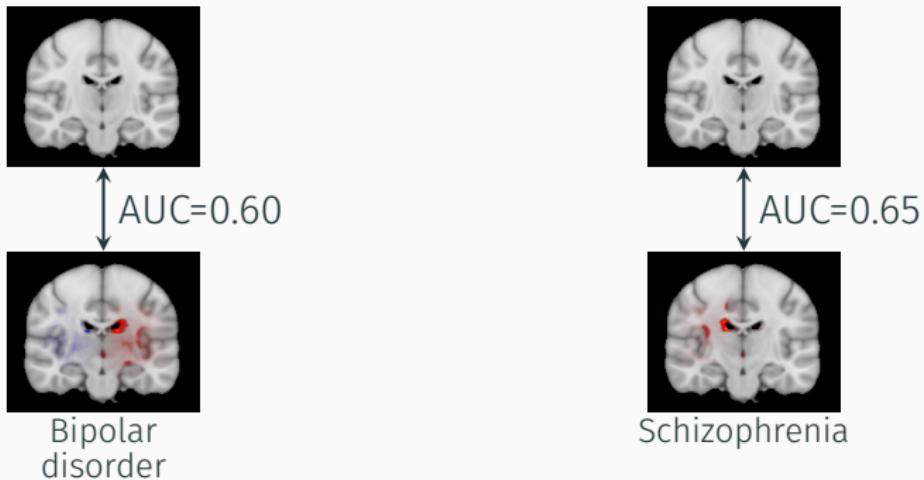
Bipolar  
disorder



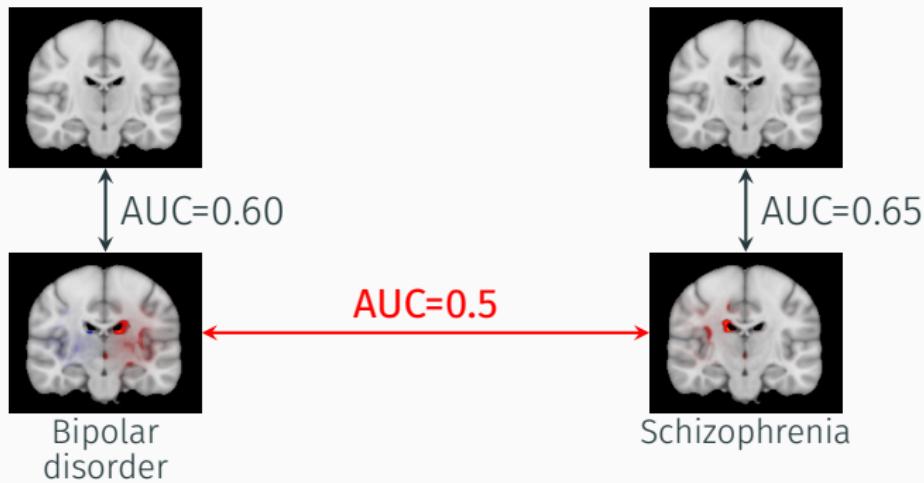
Schizophrenia



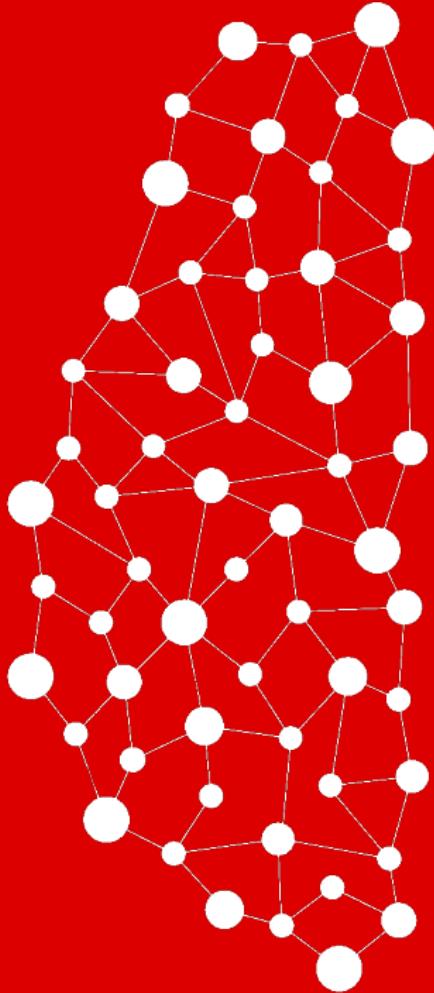
# Explainable brain age: Results



# Explainable brain age: Results



Thank you for your attention!  
estenhl@ui.no



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