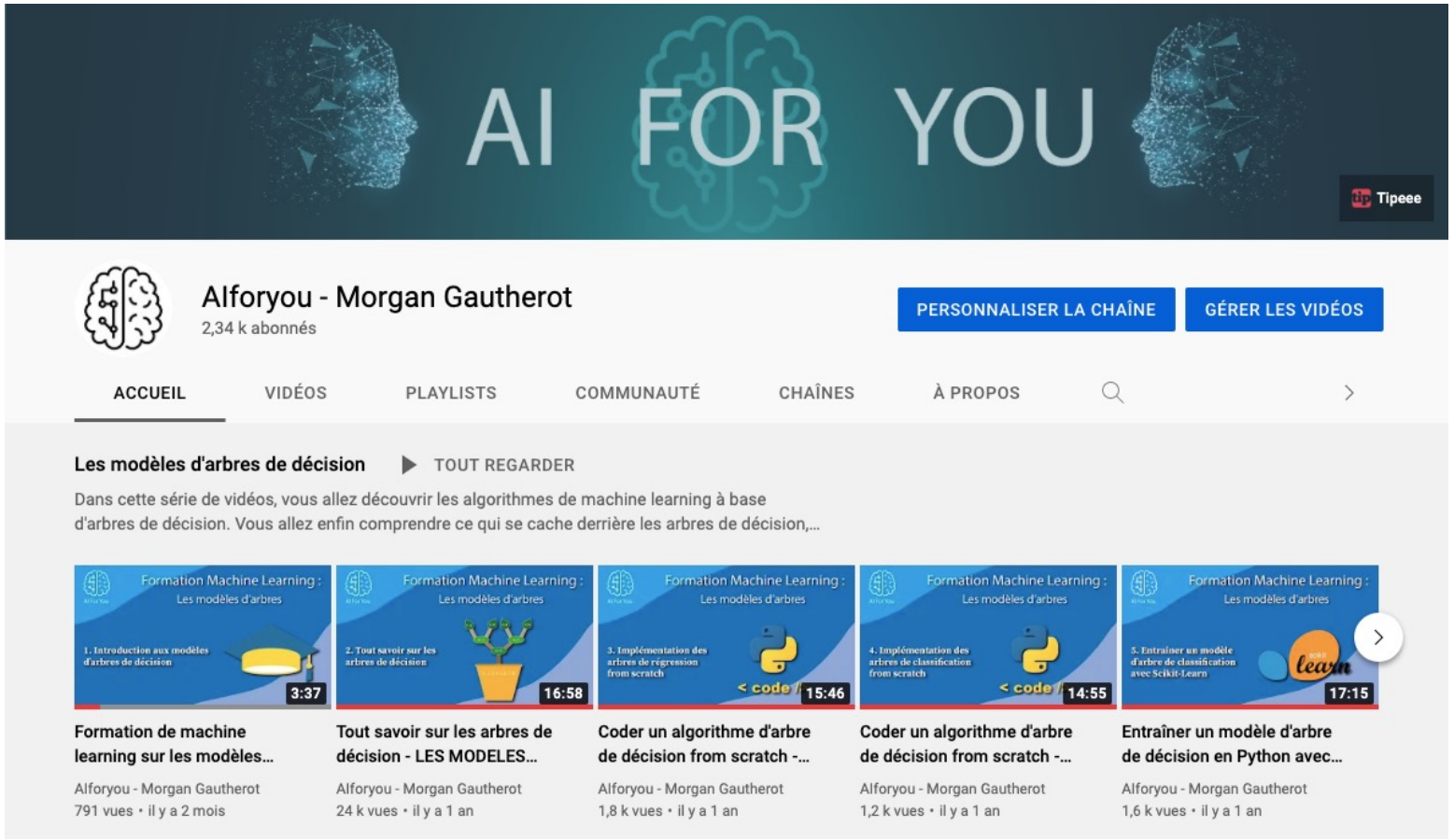
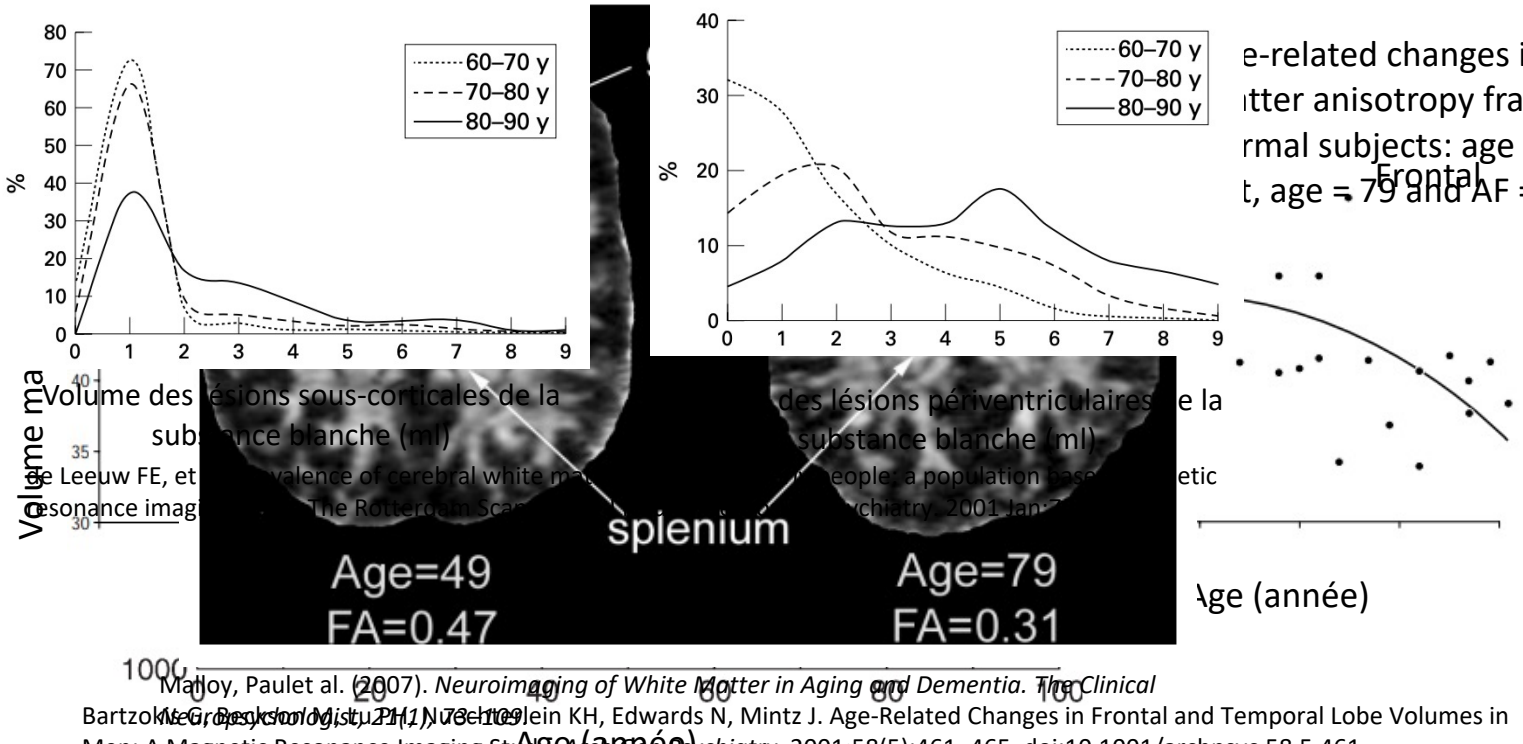
Brain age prediction

Morgan Gautherot
03/02/2022

YouTube channel



Brain development



e-related changes in anterior white
itter anisotropy fraction (AF) in
rmal subjects: age = 49 and AF = 0.47
t, age = 79 and AF = 0.30 right.

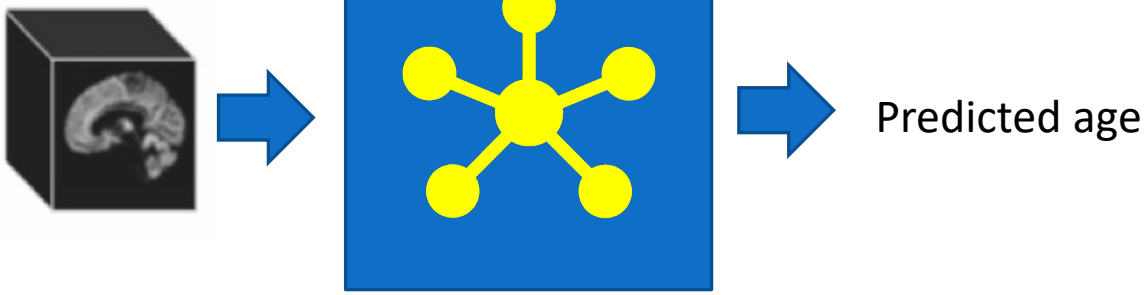
de Leeuw FE, et al. Prevalence of cerebral white matter lesions in elderly people: a population based magnetic resonance imaging study. The Rotterdam Scan Study. J Neurol Neurosurg Psychiatry. 2001 Jan;70(1):9-14.

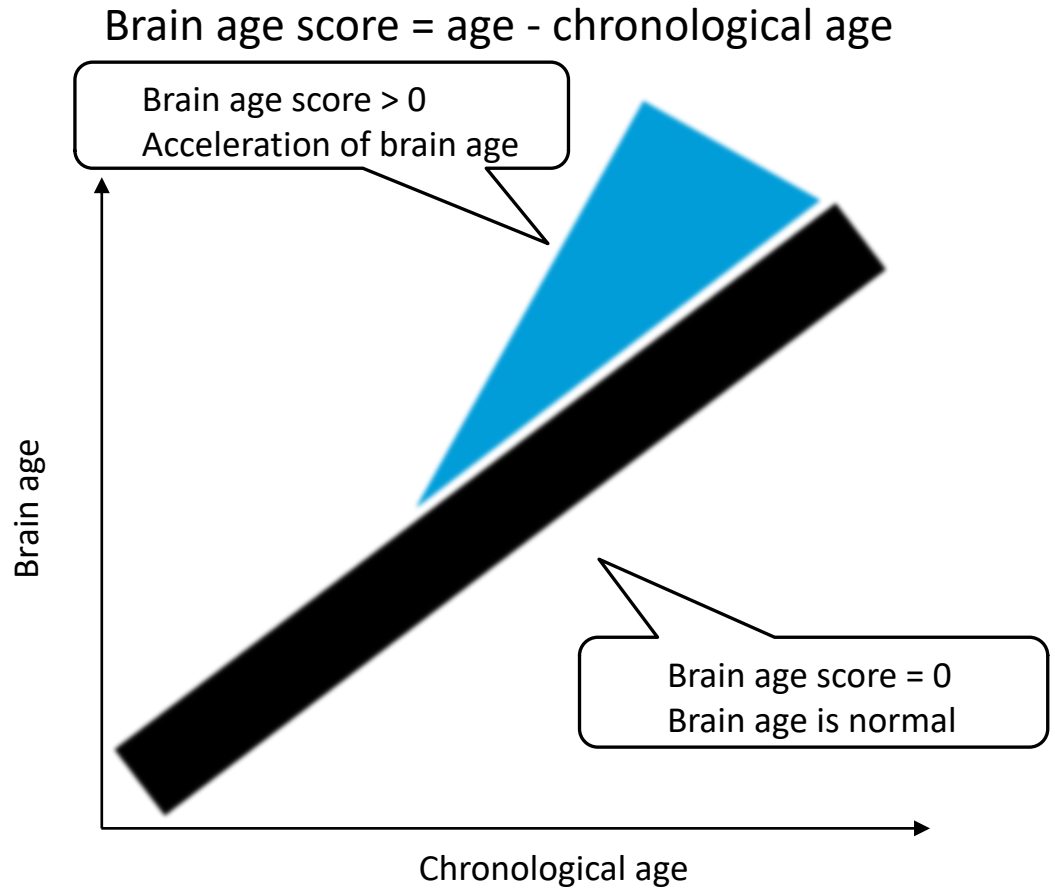
Malloy, Paulet al. (2007). *Neuroimaging of White Matter in Aging and Dementia. The Clinical Neuropsychologist, 21(1), 73-109.*

Bartzokis G, Beckson M, Lu PH, Nuechterlein KH, Edwards N, Mintz J. Age-Related Changes in Frontal and Temporal Lobe Volumes in Men: A Magnetic Resonance Imaging Study. *Arch Gen Psychiatry.* 2001;58(5):461–465. doi:10.1001/archpsyc.58.5.461

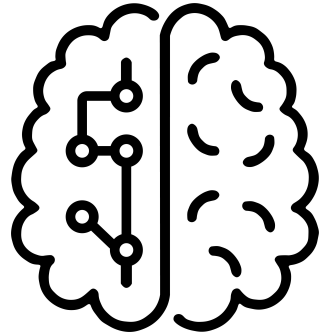
Hedman AM et al. Human brain changes across the life span: a review of 56 longitudinal magnetic resonance imaging studies. *Hum Brain Mapp*. 2012;33(8):1987-2002. doi:10.1002/hbm.21334

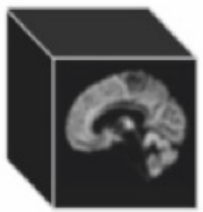
Le score d’âge cérébral





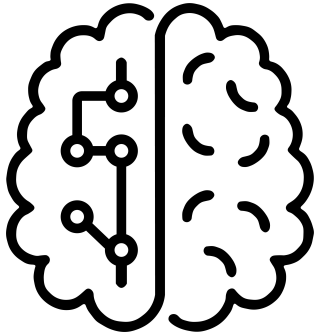
Classic machine learning



Data	Extraction of characteristics	Prediction	Performance
	Raw data Grey matter White matter Cerebral spinal fluid Cortical thickness Cortical surface Sub-cortical volumes	Gaussian Processes Regression Cole, J., et al. Prediction of Brain Age Suggests Accelerated Atrophy after Traumatic Brain Injury. Ann. Neurol. 77:571–581, 2015.	MAE* 4.66
		Naive bayes Lancaster, J., et al. Optimization for Neuroimaging Pre-processing in Brain Age Prediction. Front. Aging Neurosci. 10:28, 2018.	MAE* 5.08
		Relevance Vector Machine Franke, K., et al. Estimating the age of healthy subjects from T1-weighted MRI scans using kernel methods: Exploring the influence of various parameters. NeuroImage 50:883–892, 2010.	MAE* 4.98
		Random forest Liem, F., et al., Predicting brain-age from multimodal imaging data captures cognitive impairment. NeuroImage 148:179–188, 2017.	MAE* 4.83

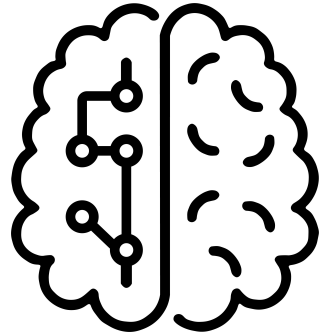
MAE* = Mean absolute error

Healthcare in the age of Big Data

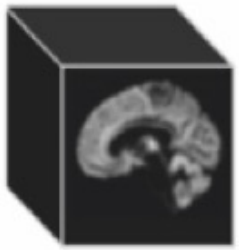


Etude	n	Sujet	Age moyen ± écart type (année)	Tranche d'âge, min-max (année)	Femme, n (%)	Constructeur
IXI	561	561	48.11 ± 16.73	19-86	312 (55%)	Philips
HCP	1783	1113	28.76 ± 3.7	22-37	815 (45%)	Siemens
COBRE	238	94	38.18 ± 11.53	18-65	64 (26%)	Siemens
MCIC	264	95	33.59 ± 12.21	18-60	80 (30%)	Siemens
NmorphCH	141	44	31.37 ± 8.42	20-46	66 (46%)	Siemens
NKIRS	824	671	34.91 ± 20.83	6-85	505 (61%)	Siemens
PPMI	248	149	60.90 ± 11.30	30-83	85 (34%)	General Electric / Philips / Siemens
ADNI	3686	579	74.90 ± 6.87	55-95	1954 (53%)	Philips / Siemens
ABIDE	519	519	16.81 ± 7.49	6-48	92 (17%)	General Electric / Philips / Siemens
ICBM	208	208	26.52 ± 6.29	18-44	112 (53%)	Philips / Siemens

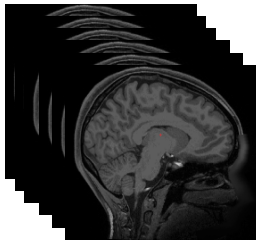
Deep learning



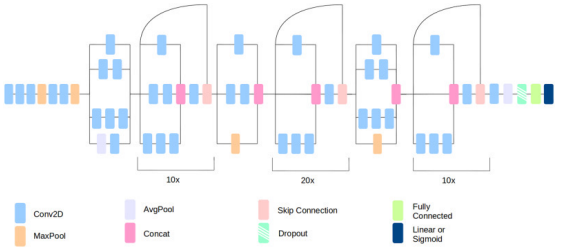
Data



2D image slicing



Prediction



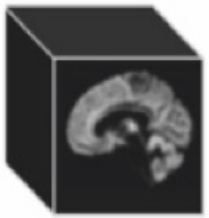
Christian Szegedy et al., 2016, arXiv : 1602.07261

Performance

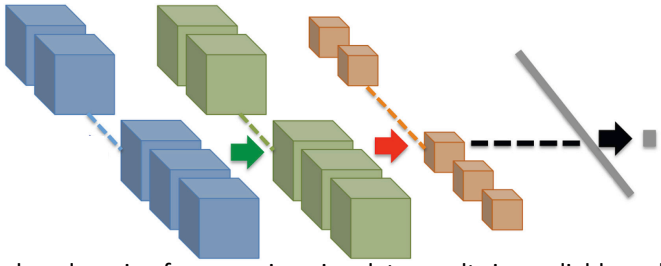
MAE* 3.68

Bashyam VM, et al. MRI signatures of brain age and disease over the lifespan based on a deep brain network and 14 468 individuals worldwide. Brain. 2020 Jul 1;143(7):2312-2324.

Data



Prediction



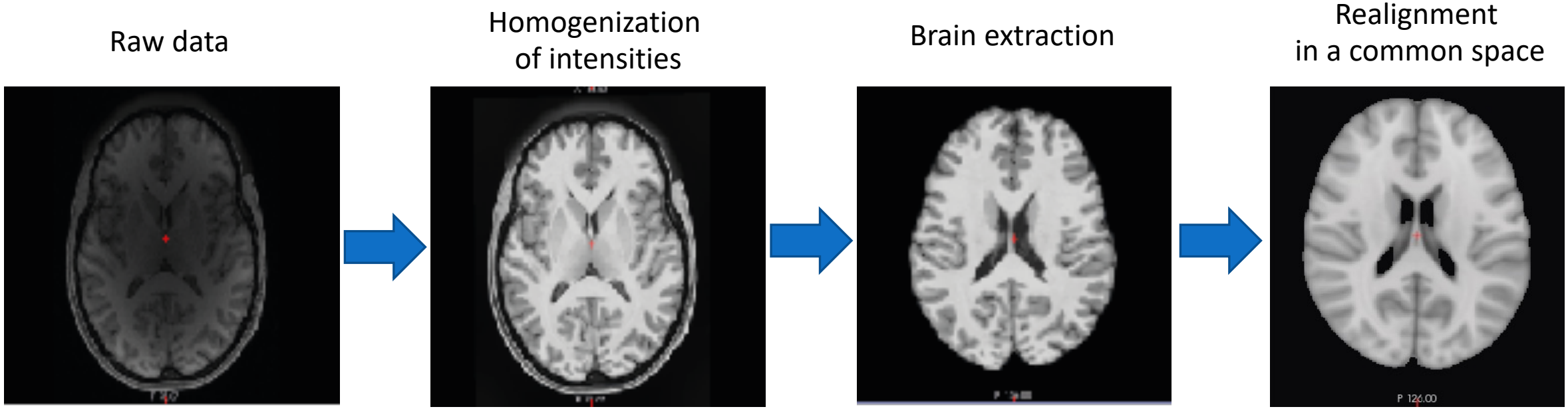
Performance

MAE* 4.16

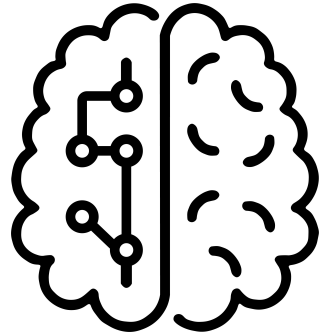
Cole, J. H., et al., Predicting brain age with deep learning from raw imaging data results in a reliable and heritable biomarker. NeuroImage 163:115–124, 2017.

MAE* = Mean absolute error

Prétraitements



Age prediction model



Number of parameters: 904 325

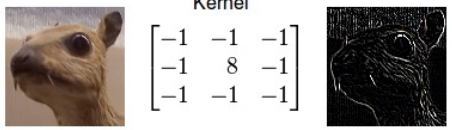
Nb of filters 4 x $2^{n° \text{ bloc}}$

Pooling f 2x2x2 s 2x2x2

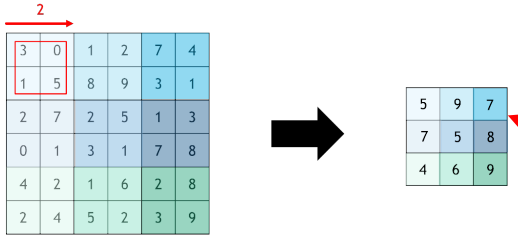
Conv filter 3D 3x3x3

Activation function: ReLU

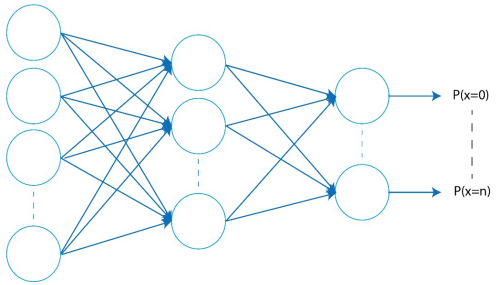
Convolution layer



Pooling layer

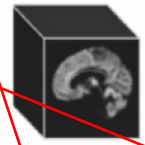


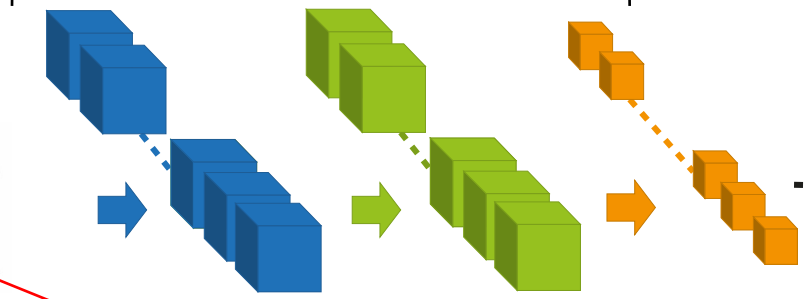
Dense layer



X 5

3D T1





Age

Cole, J. H., et al.. NeuroImage 163:115–124, 2017.

Convolution

Convolution + Batch normalisation

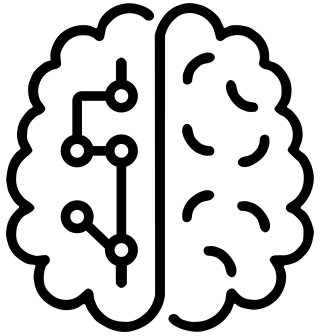
Max-pooling

Dense

$$J(w) = \frac{1}{m}\sum_{i=1}^{m}|y_i - \hat{y}_i|$$

Mean absolute error ou MAE

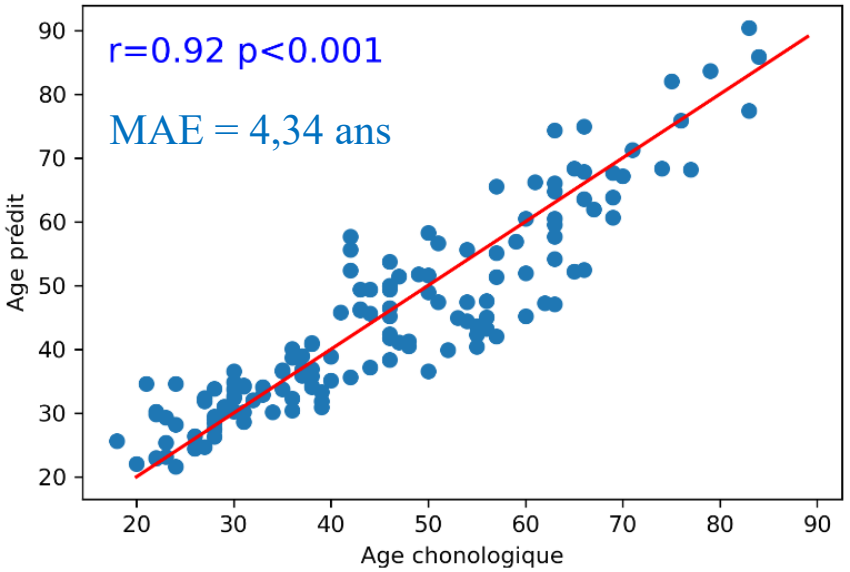
Training the model



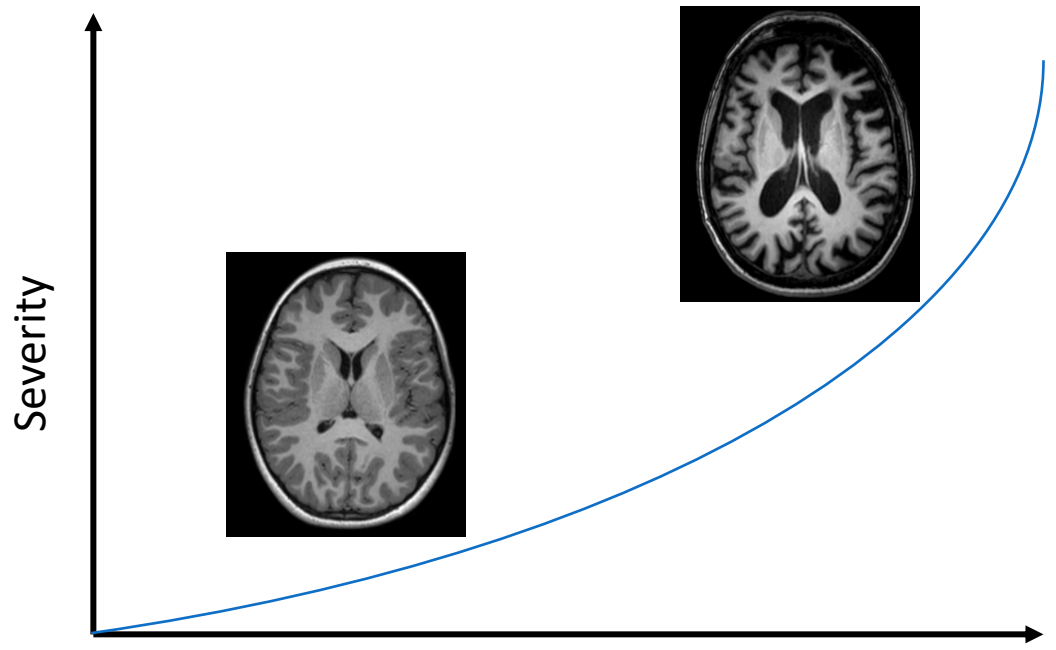
Cross validation

Nombre de validation	1	2	3	4	5	Moyenne ± écart type
MAE validation (année)	3.85	2.74	3.06	2.77	3.48	3.18±0.43

Testing set



Brain age goal



Alzheimer vs healthy control

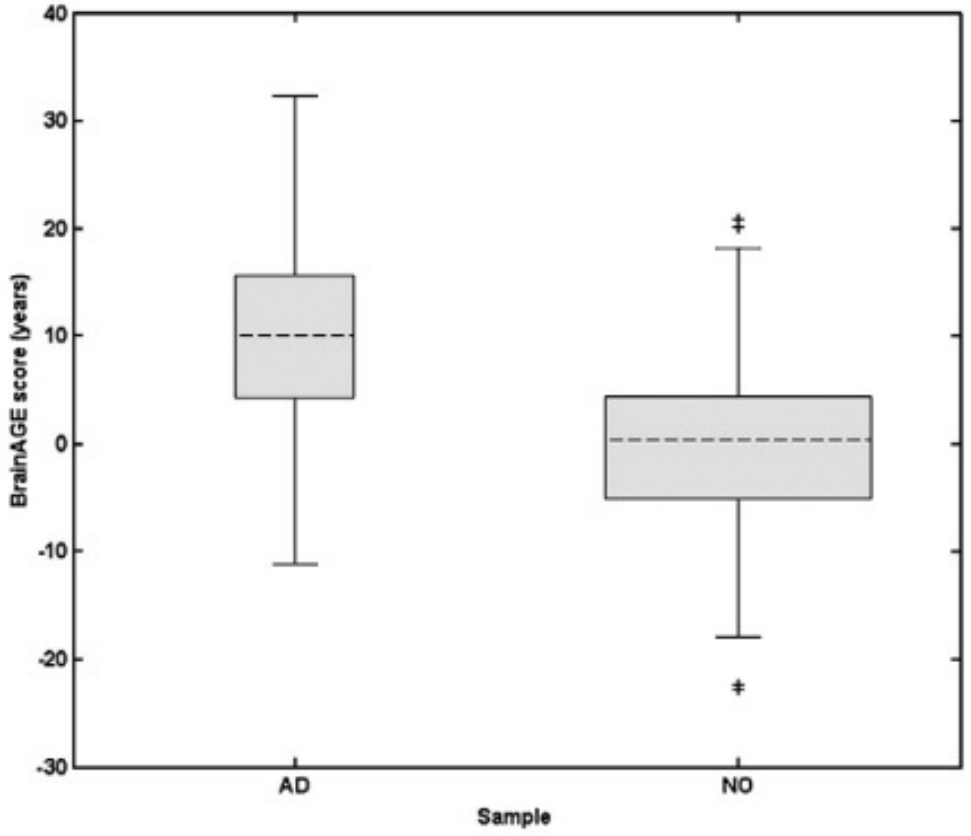
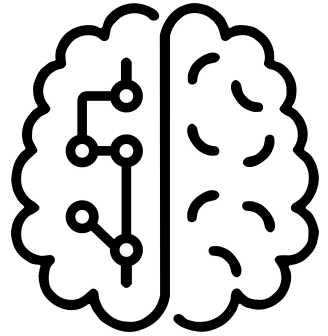


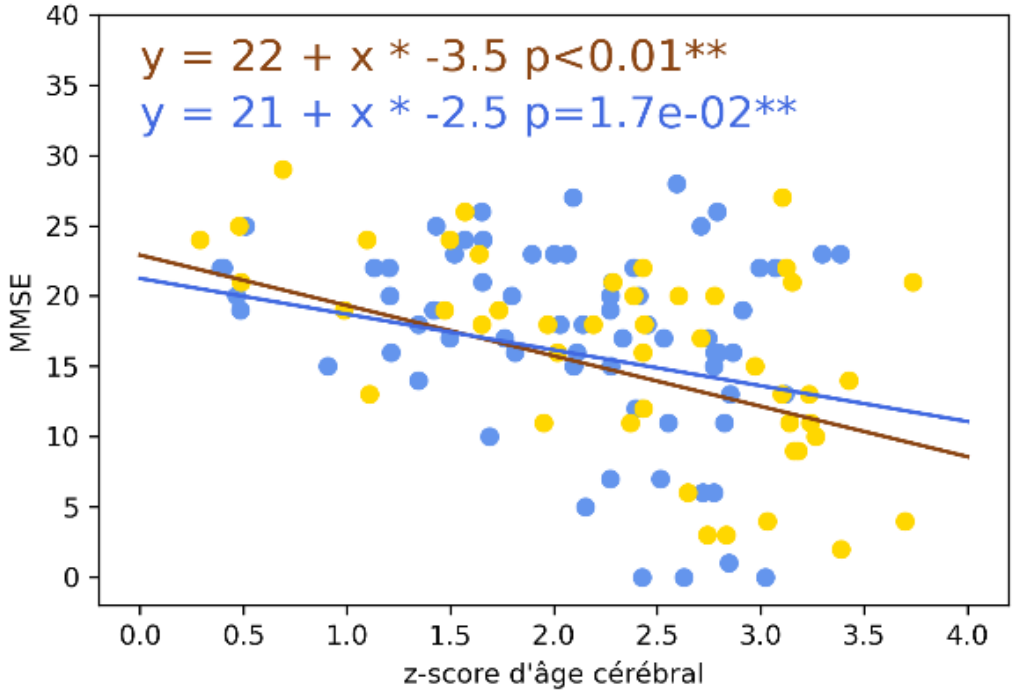
Fig. 10. Shown are box plots with BrainAGE scores (in years) for the two samples from the ADNI database (AD with CDR = 1, NO with CDR = 0). The gray boxes contain the values between the 25th and 75th percentiles of the samples, including the median (dashed line). Lines extending above and below each box symbolize data within 1.5 times the interquartile range (outliers are displayed with a +). The width of the boxes depends on the sample size.

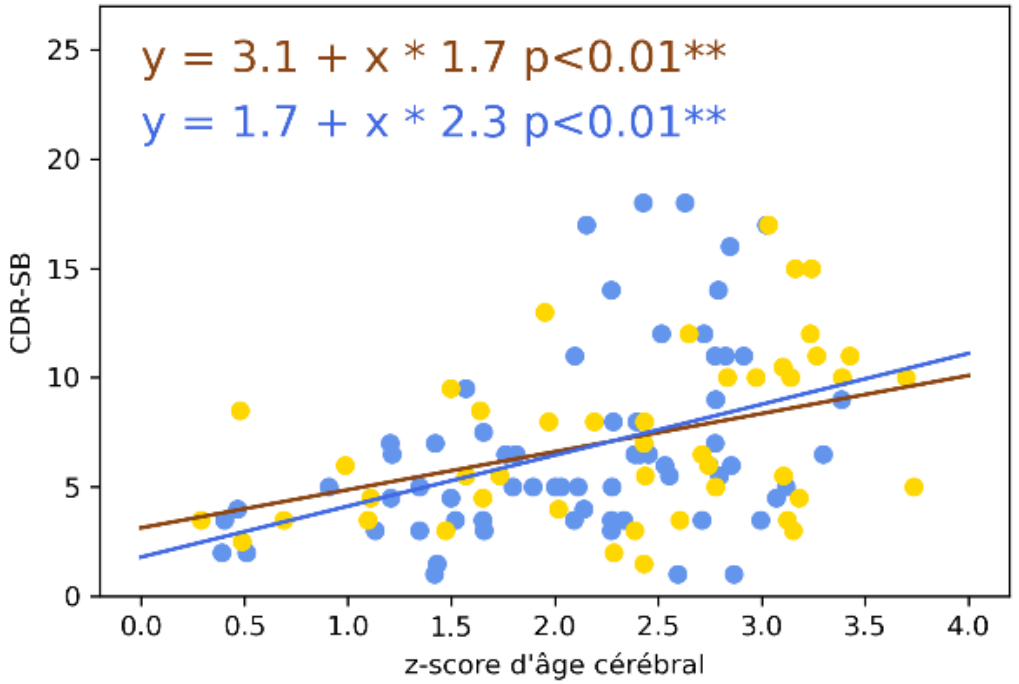
Franke K, et al. Alzheimer's Disease Neuroimaging Initiative. Estimating the age of healthy subjects from T1-weighted MRI scans using kernel methods: exploring the influence of various parameters. Neuroimage. 2010 Apr 15;50(3):883-92

brain age and mental health score



Mnésique Non-mnésique





Brain age in psychatric diseases