Detecting individual-level deviations in brain morphology with Layerwise Relevance Propagation

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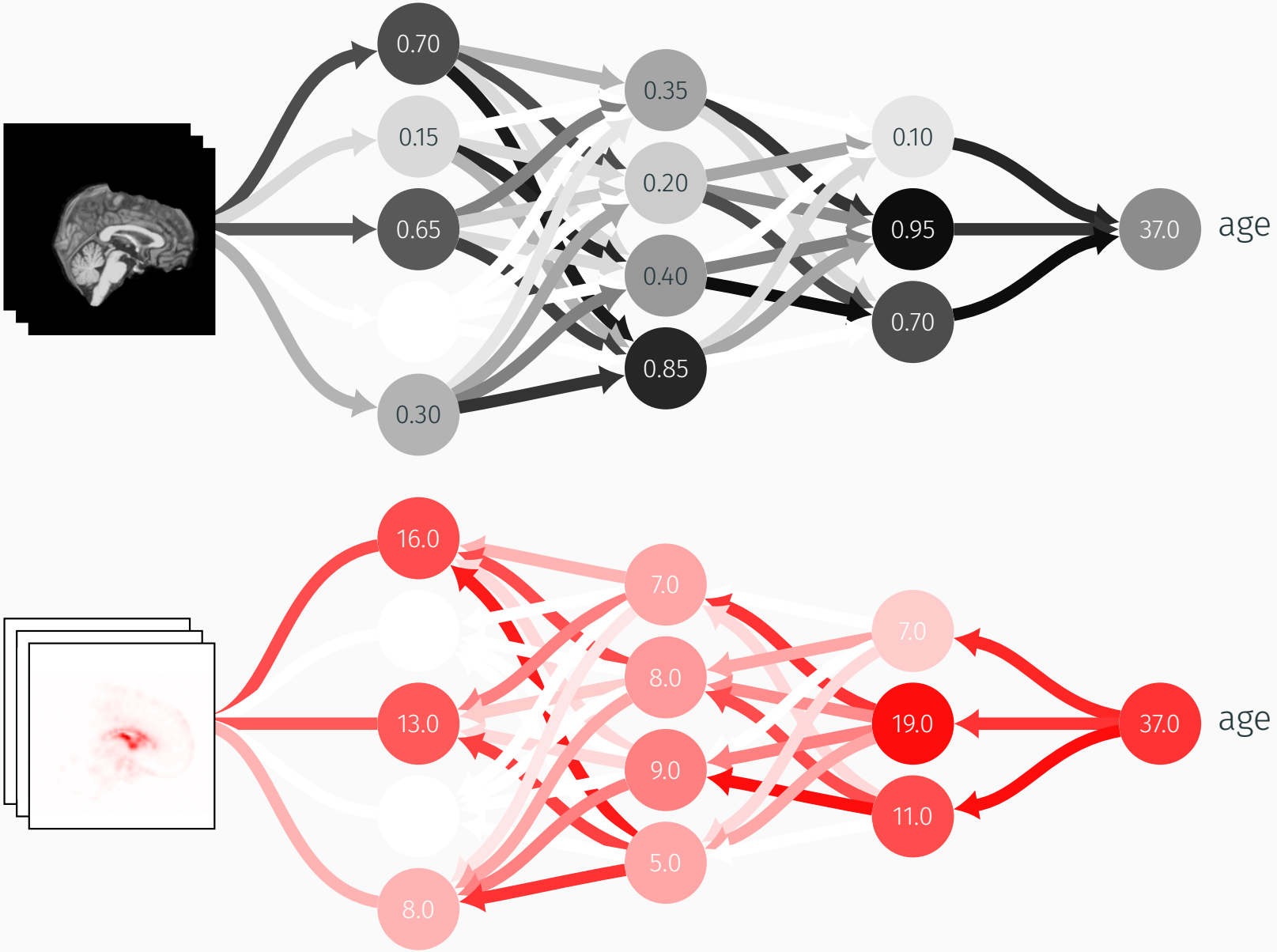
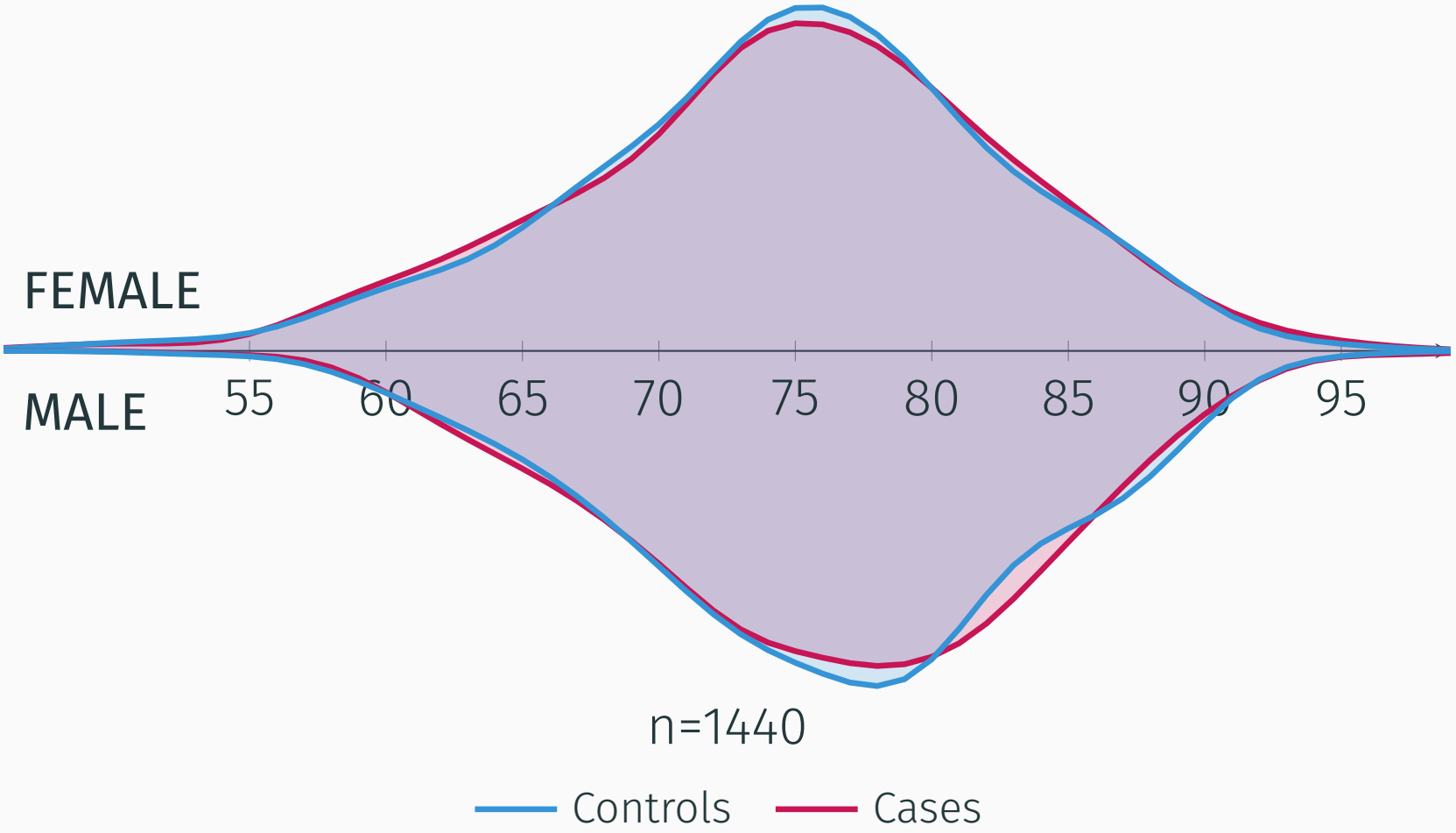
Overview

1. Build a pipeline for producing phenotype-specific, individual-level deviation-maps from structural MRIs using a CNN and LRP
2. Validate the methodology in dementia patients
3. Application (Schizophrenia?)

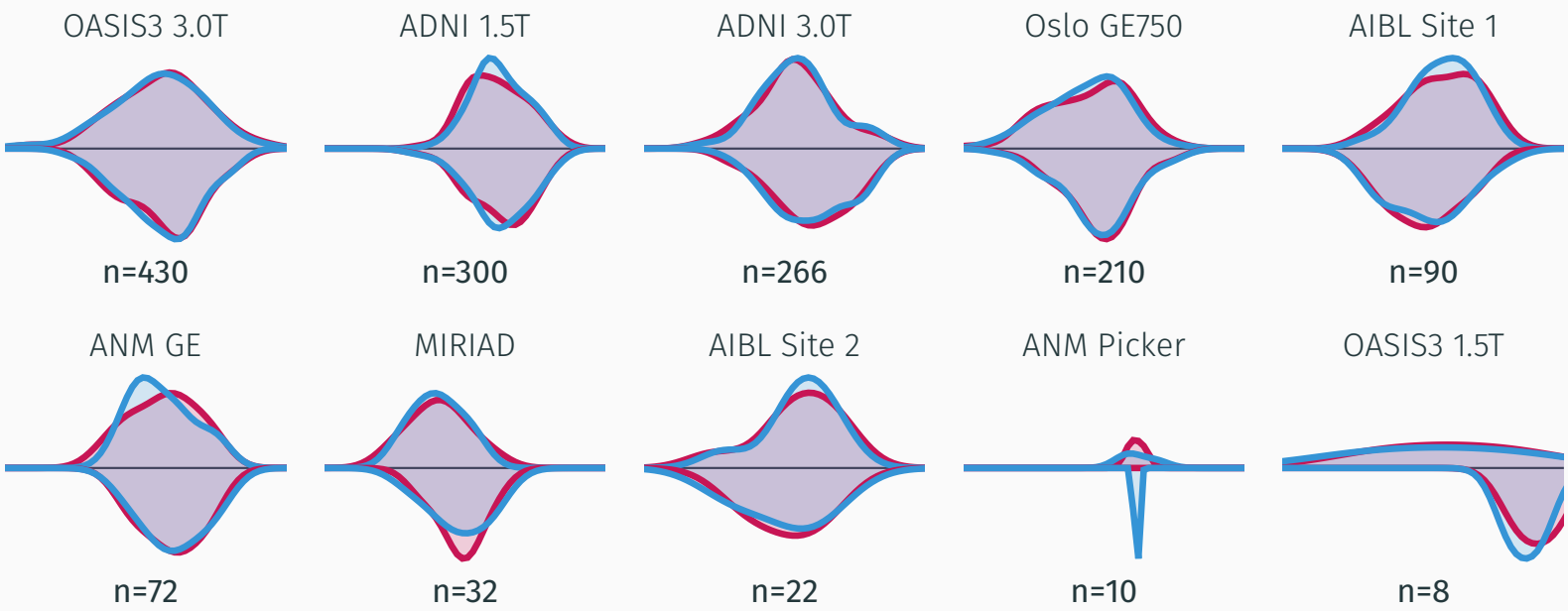
Layerwise Relevance Propagation recap



Dementia: Dataset



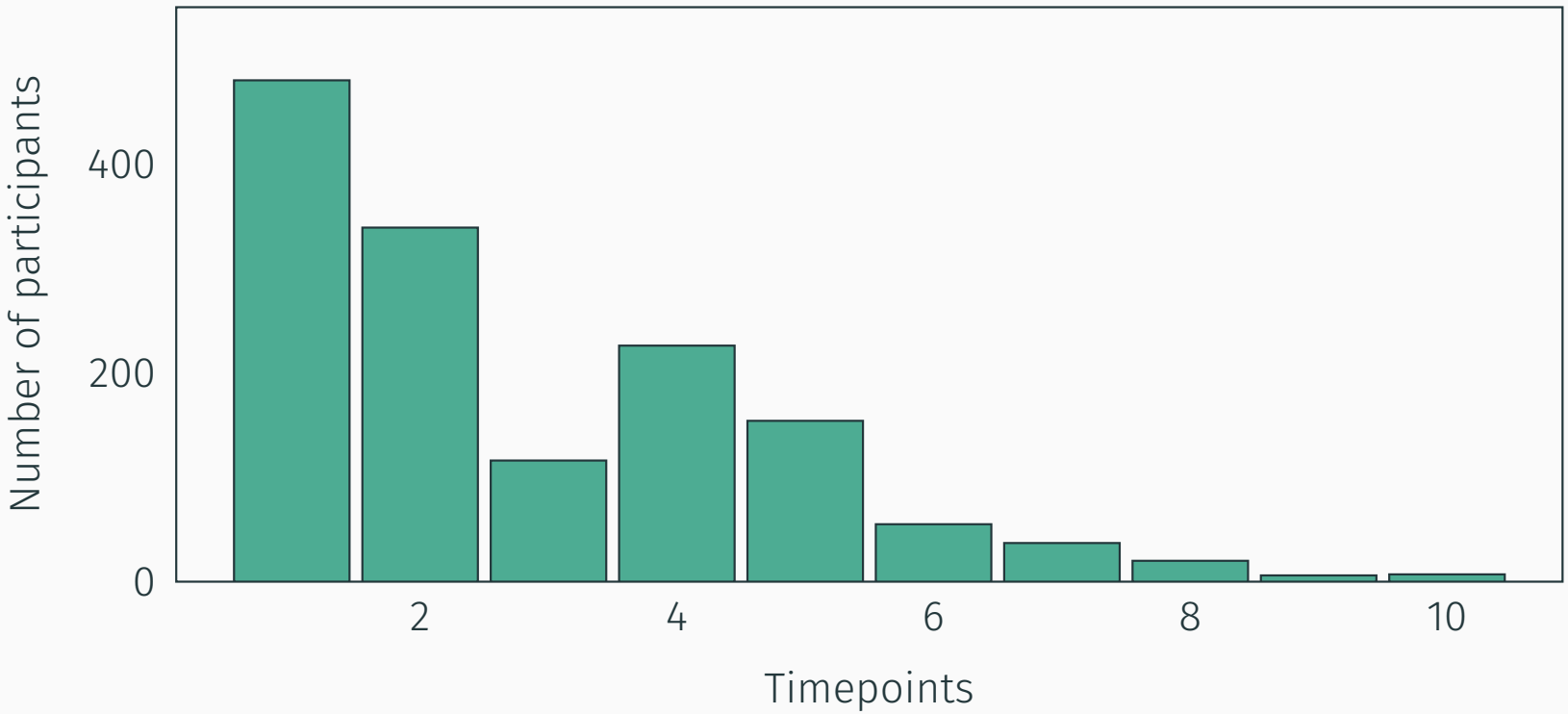
Dementia: Dataset



Dementia: Dataset

Dataset	Controls	Patients
AddNeuroMed	MMSE ≥ 24	MMSE < 19
ADNI	Group = CN	Group = AD
AIBL	Group = DXNORM	Group $\in$ {DXAD, DXOTHDEM}
CADDementia	?	?
Demgen	-	DX $\in$ {AD, OtherDem, UnspecDem, VaD}
MIRIAD	Group = Control	Group = AD
OASIS3	NORMCOG = 1	NORMCOG = 0 & DEMENTED = 1
StrokeMRI	Group = Control	-
TOP	diagnosis = CTRL	-

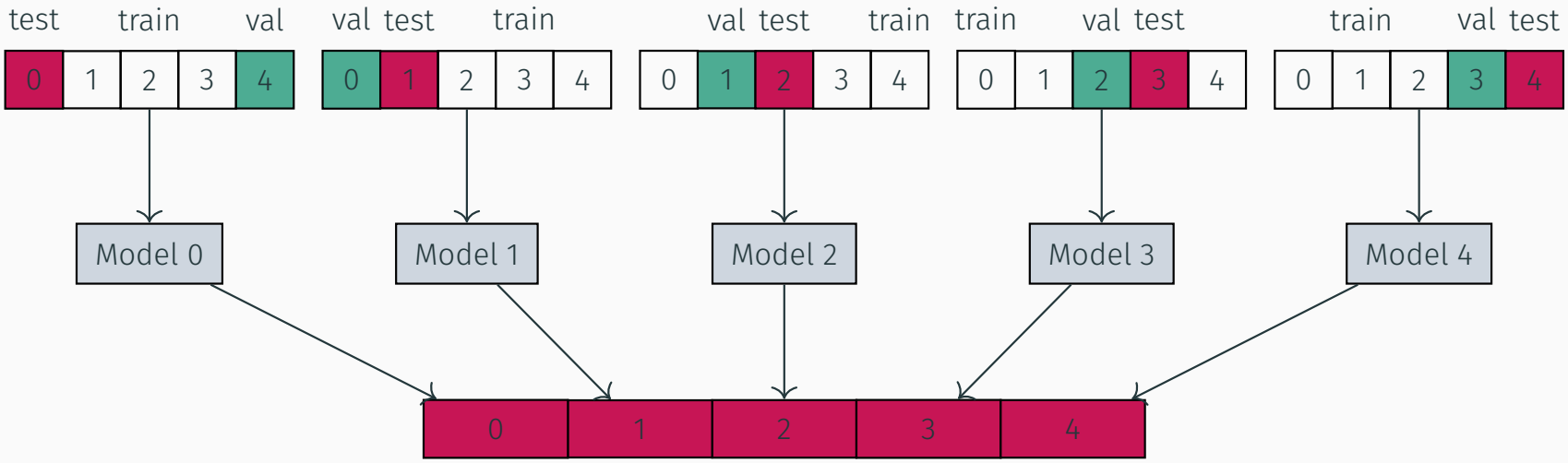
Dementia: Dataset



Dementia: Modelling

Binary SFCN

Dementia: Modelling



Out-of-sample predictions and relevance maps

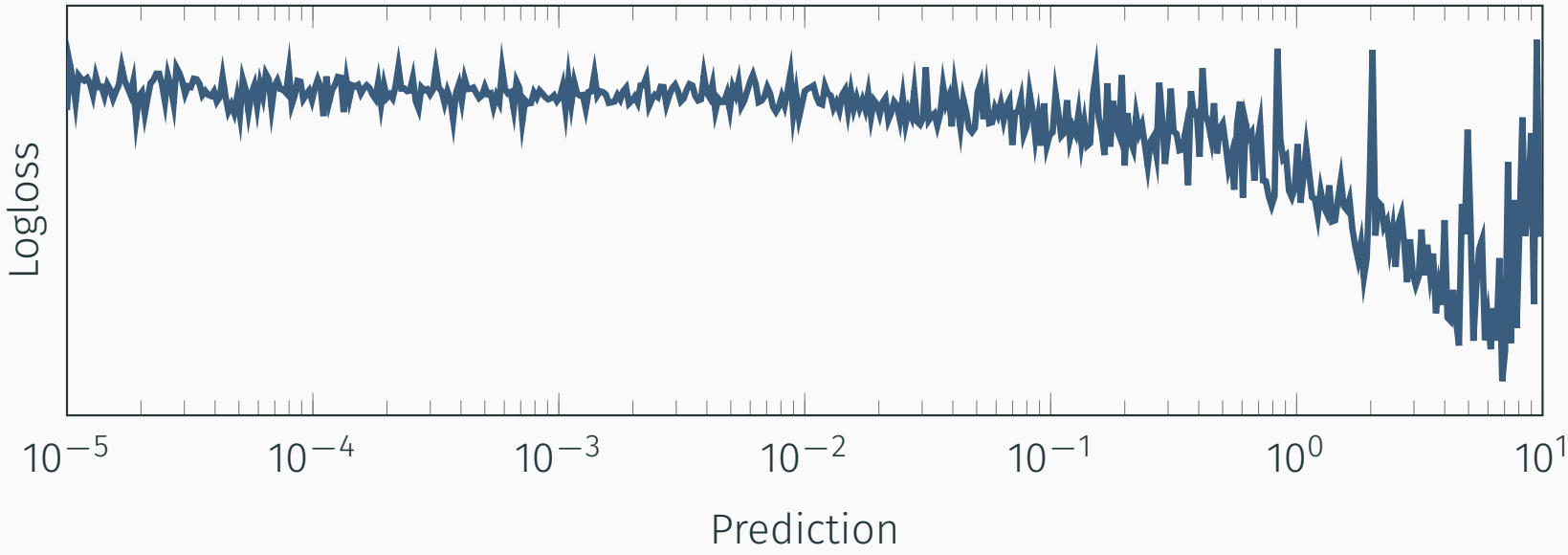
Dementia: Modelling

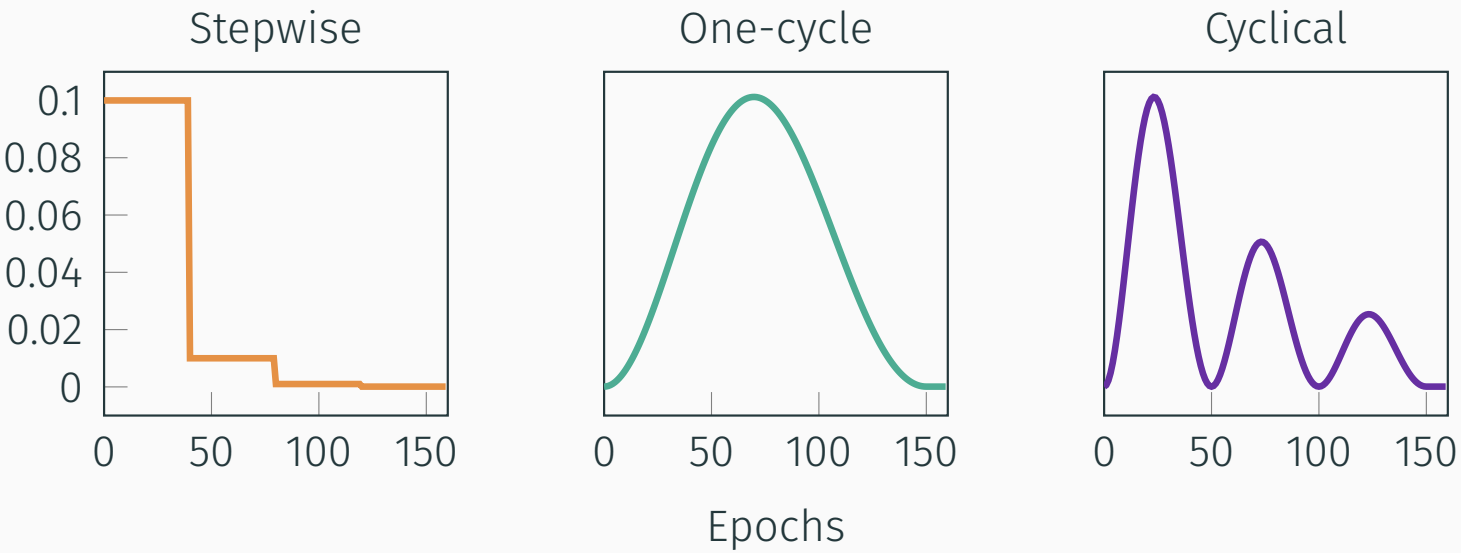
Parameterization

Augmentation	Light augmenter	Heavy augmenter
Flip	0.5,0.0,0.0[1]	0.5,0.0,0.0[1]
Shift	[-5,5][2]	[-5,5][2]
Zoom	-	[-0.05,0.05][2]
Rotation	-	[-5,5][2]
Noise	-	[0, 0.1][2]
Intensity	-	[0, 0.2][2]
Blur	-	3[3] (0.2)[2]
Contrast	-	?
Crop box (size)	[0, 50][2]	[0, 50][2]

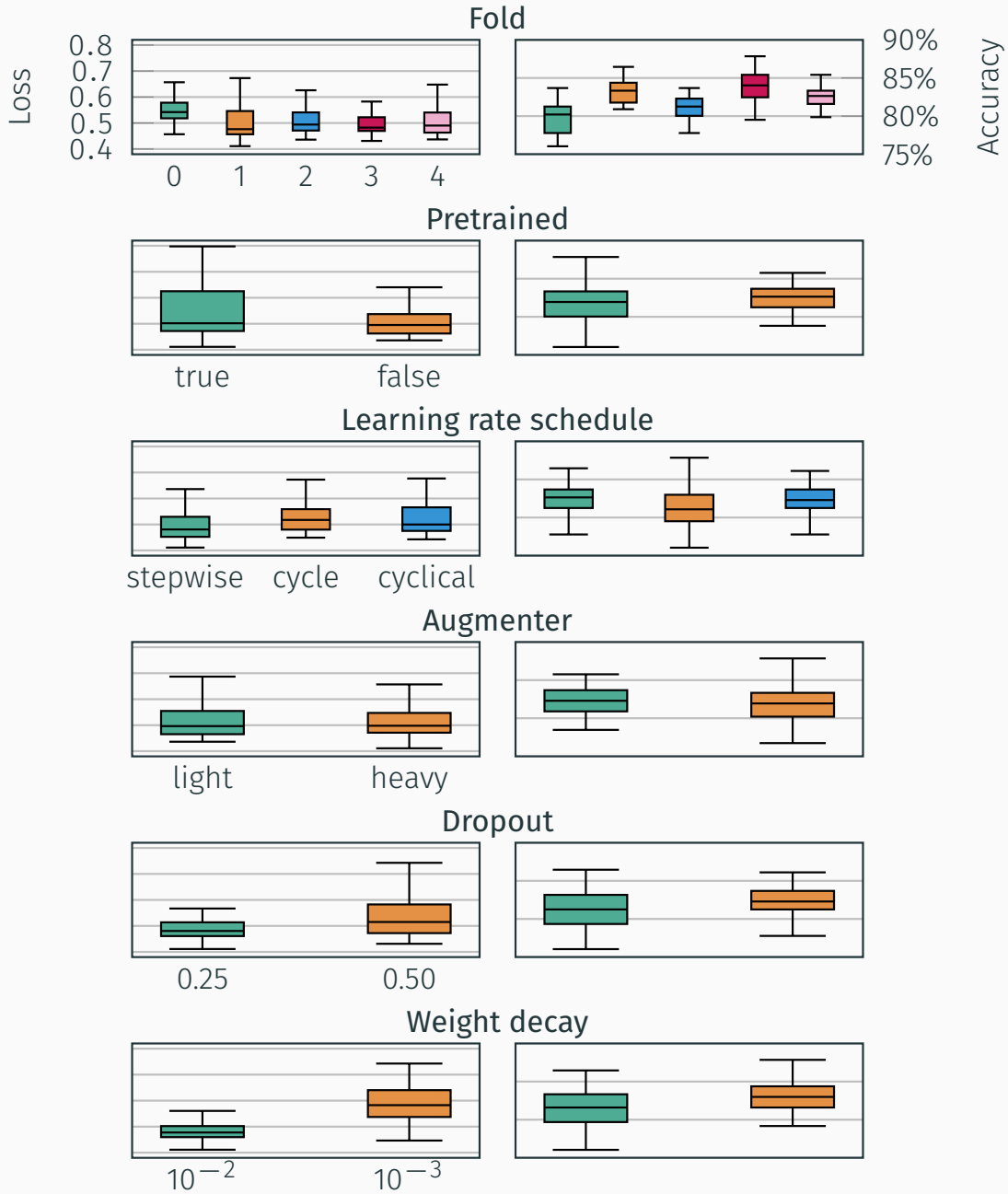
(1) Probability of occuring per image per epoch
(2) Parameter drawn from range per image per epoch
(3) Fixed kernel size

Dementia: Modelling



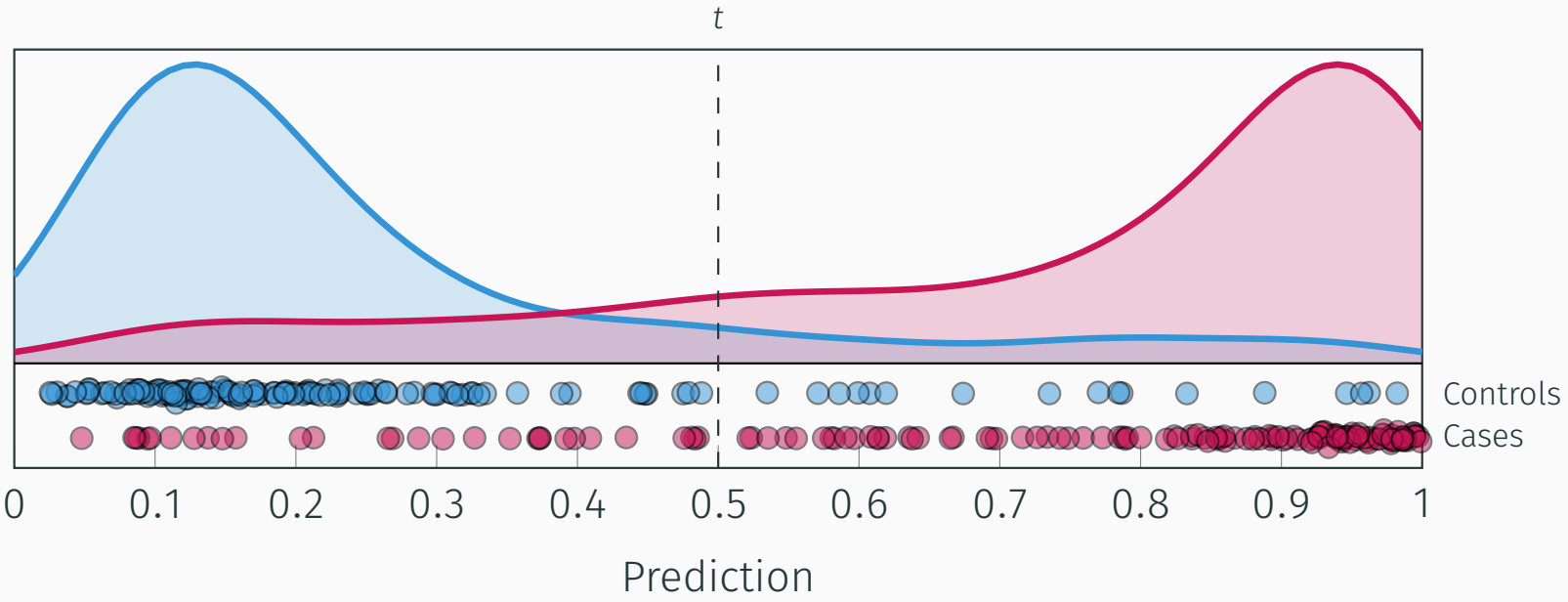


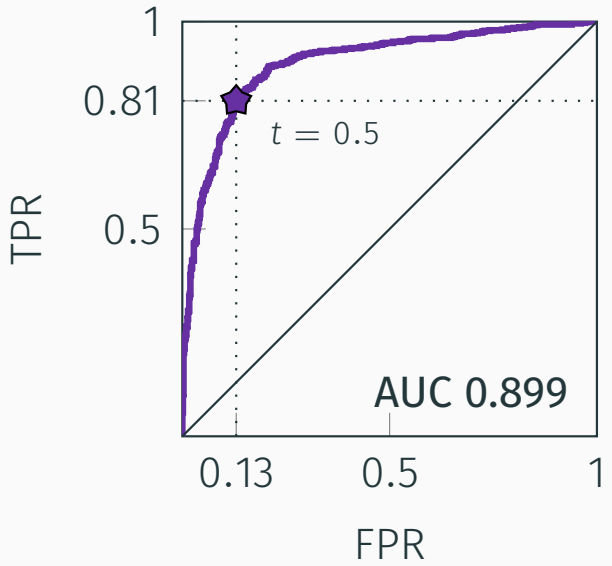
Dementia: Modelling



Dementia: Modelling

Dementia: Predictive performance





		Predicted 0	Predicted 1
Observed	0	626	94
	1	138	582

Accuracy: 83.88%

Dementia: Predictive performance

Site	Size	AUC	Accuracy
OASIS3 3.0T	430	0.841	76.9
ADNI 1.5T	300	0.915	87.0
ADNI 3.0T	266	0.951	88.3
Oslo GE750	210	0.915	82.8
AIBL Site 1	90	0.920	87.7
ANM GE	72	0.853	81.9
MIRIAD	32	1.00	100
AIBL Site 2	22	0.892	86.3
ANM Picker	10	0.840	80.0
OASIS3 1.5T	8	0.812	75.0

Dementia: Relevance maps

$$\text{LRP-0:} \qquad R_j^l = \sum_k \frac{a_j w_{jk}}{\sum_{0,j} a_j w_{jk}} R_k^{(l+1)}$$

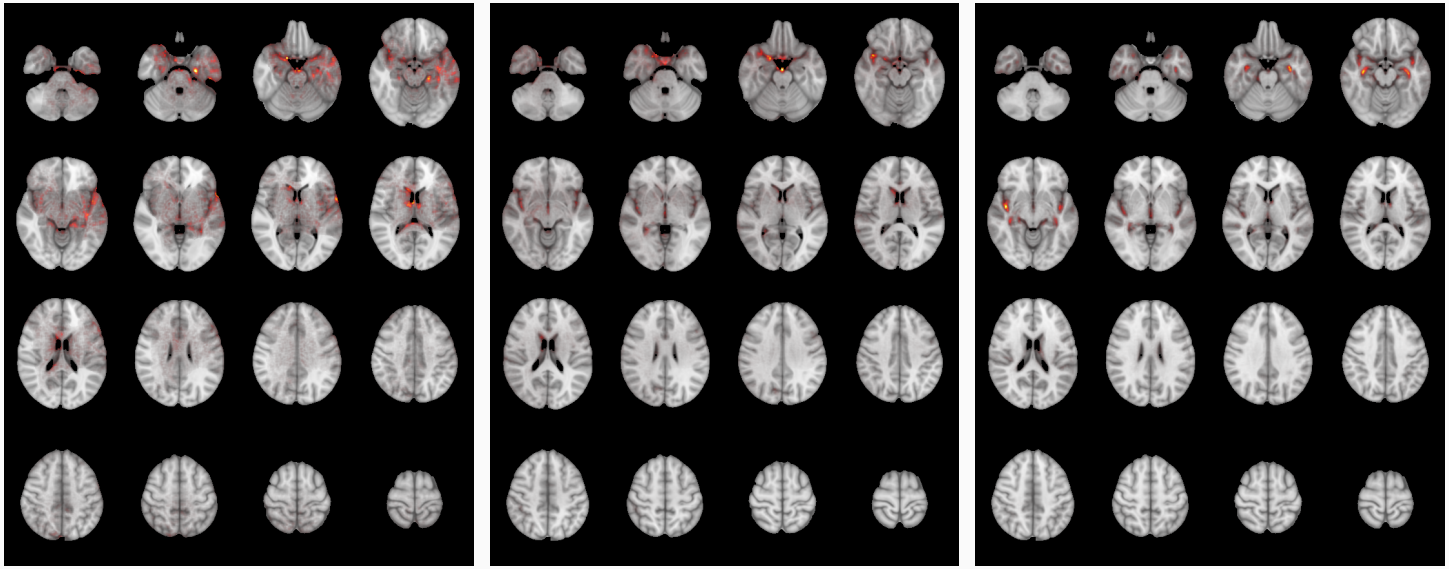
$$\text{LRP-}\epsilon\text{:} \qquad R_j^l = \sum_k \frac{a_j w_{jk}}{\sum_{0,j} a_j w_{jk} + sign(a_j w_{jk}) * \epsilon} R_k^{(l+1)}$$

$$\text{LRP-}\alpha\beta\text{:} \qquad R_j^l = \sum_k \alpha \frac{a_j w_{jk}^+}{\sum_{0,j} a_j w_{jk}} - \beta \frac{a_j w_{jk}^-}{\sum_{0,j} a_j w_{jk}} R_k^{(l+1)}$$

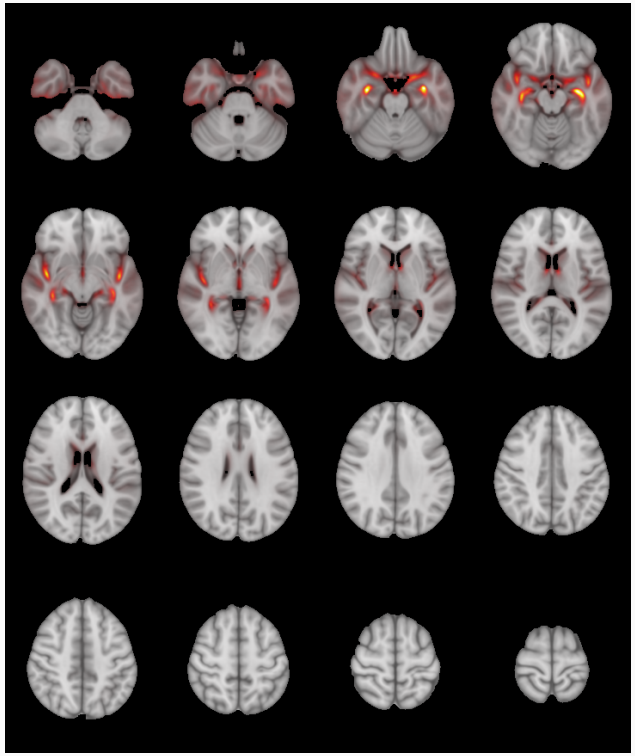
Dementia: Relevance maps

Layer	LRP Strategy
Input	-
Conv3D	{flat: True}
MaxPooling3D	-
Conv3D	{flat: True}
MaxPooling3D	-
Conv3D	{α: 1, β: 0}
MaxPooling3D	-
Conv3D	{α: 1, β: 0}
MaxPooling3D	-
Conv3D	{α: 1, β: 0}
MaxPooling3D	-
Conv3D	{α: 1, β: 0}
GlobalAveragePooling3D	-
Dropout	-
Dense	{ϵ: 0.25}

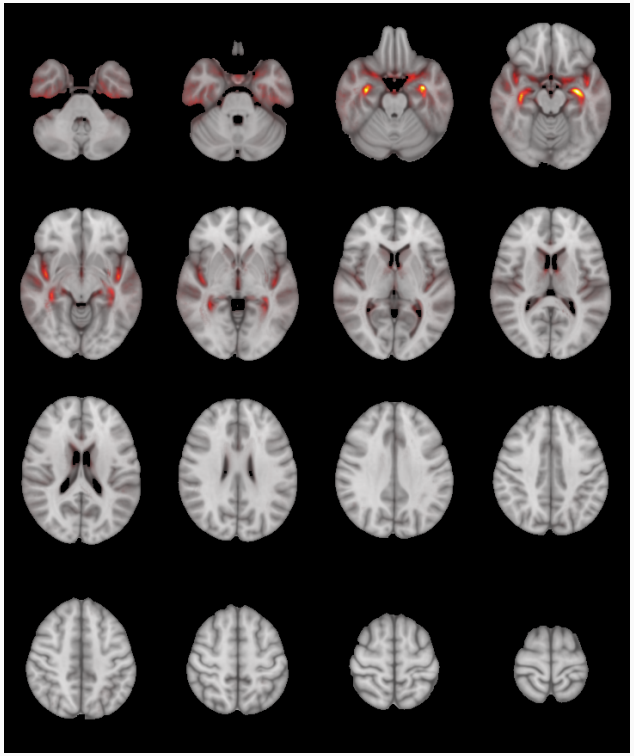
Dementia: Relevance maps



Dementia: Relevance maps

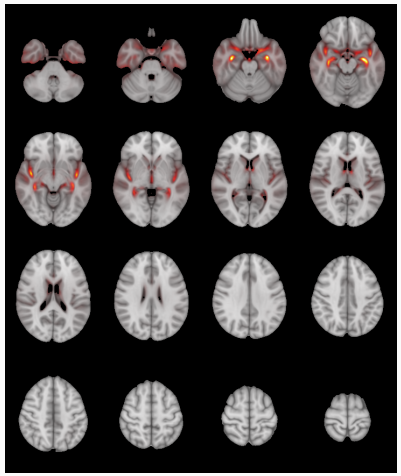


Average

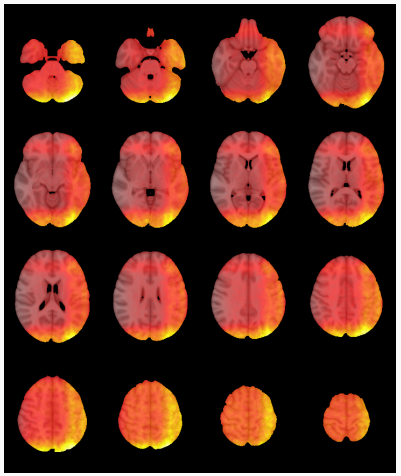


Standard deviation

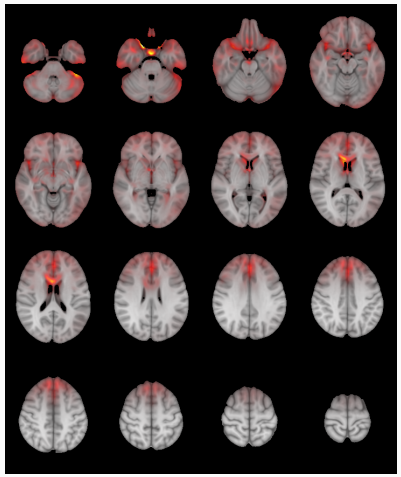
Dementia: Relevance maps



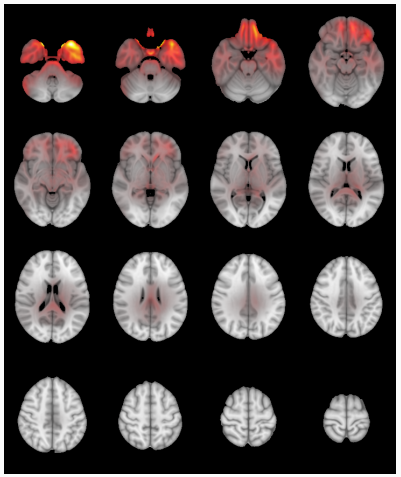
Dementia model



Dementia model with randomized images

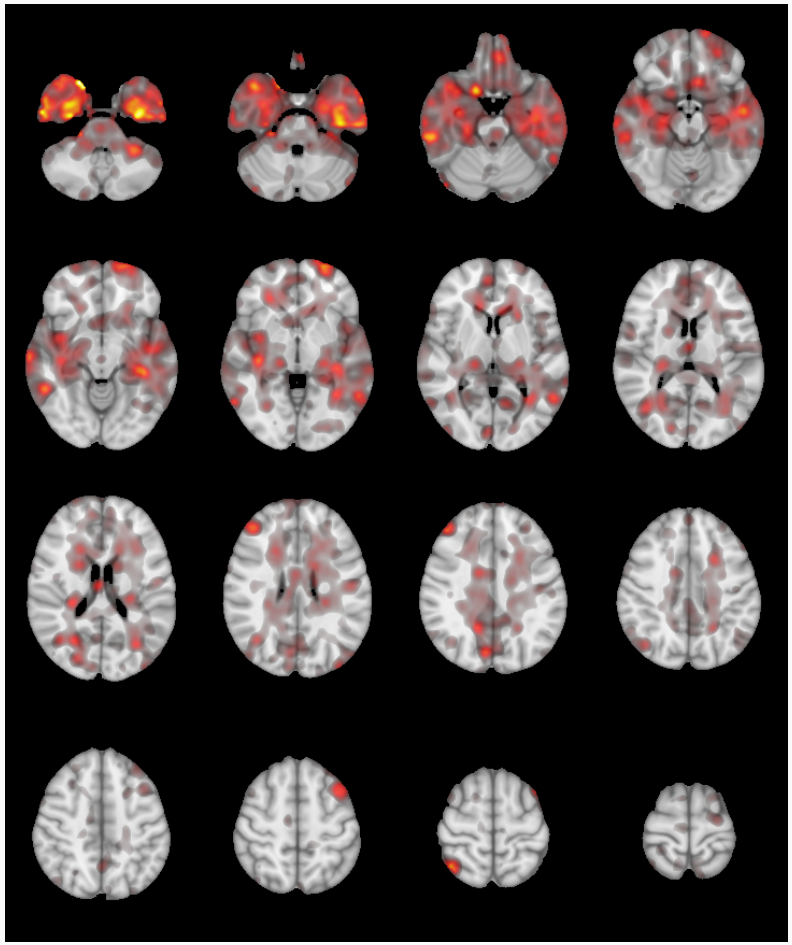


Sex model



Model with randomized weights

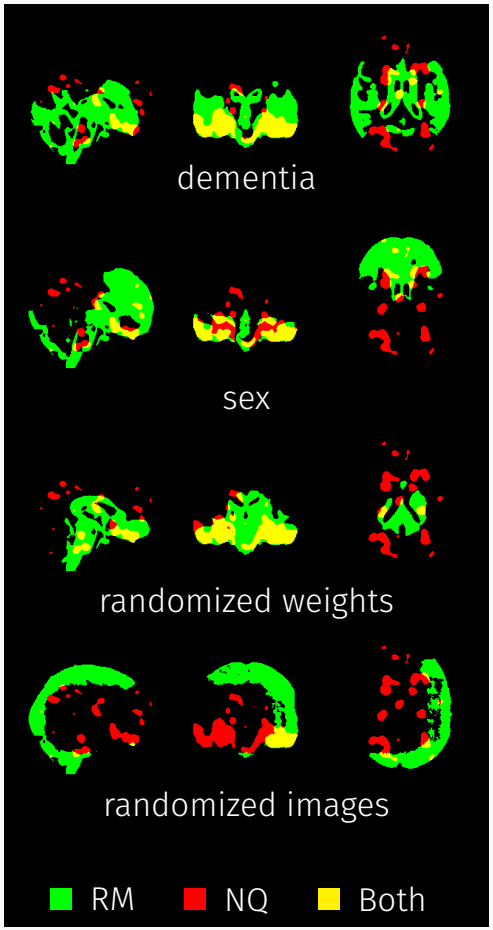
Dementia: Relevance maps



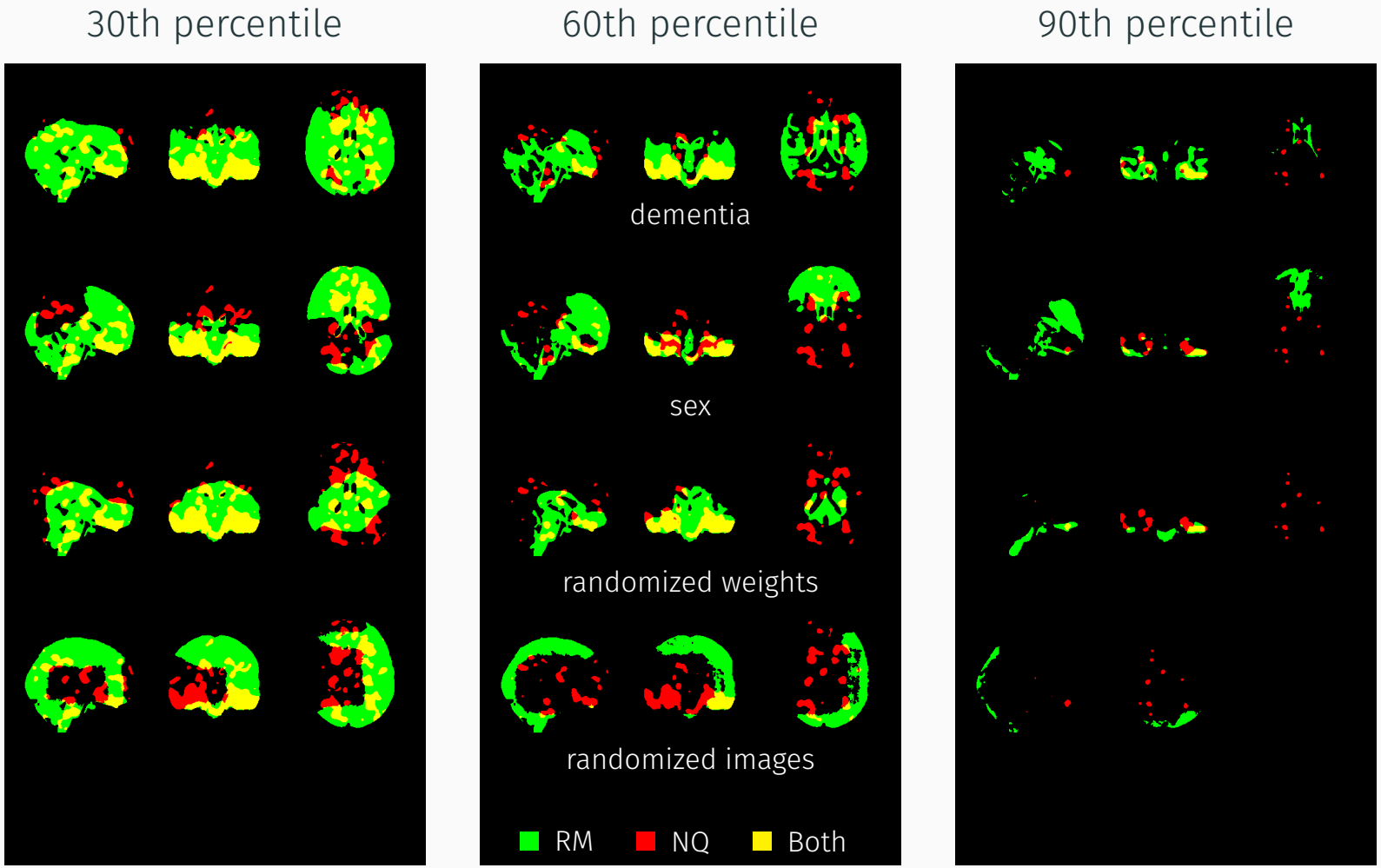
Neuroquery

Dementia: Relevance maps

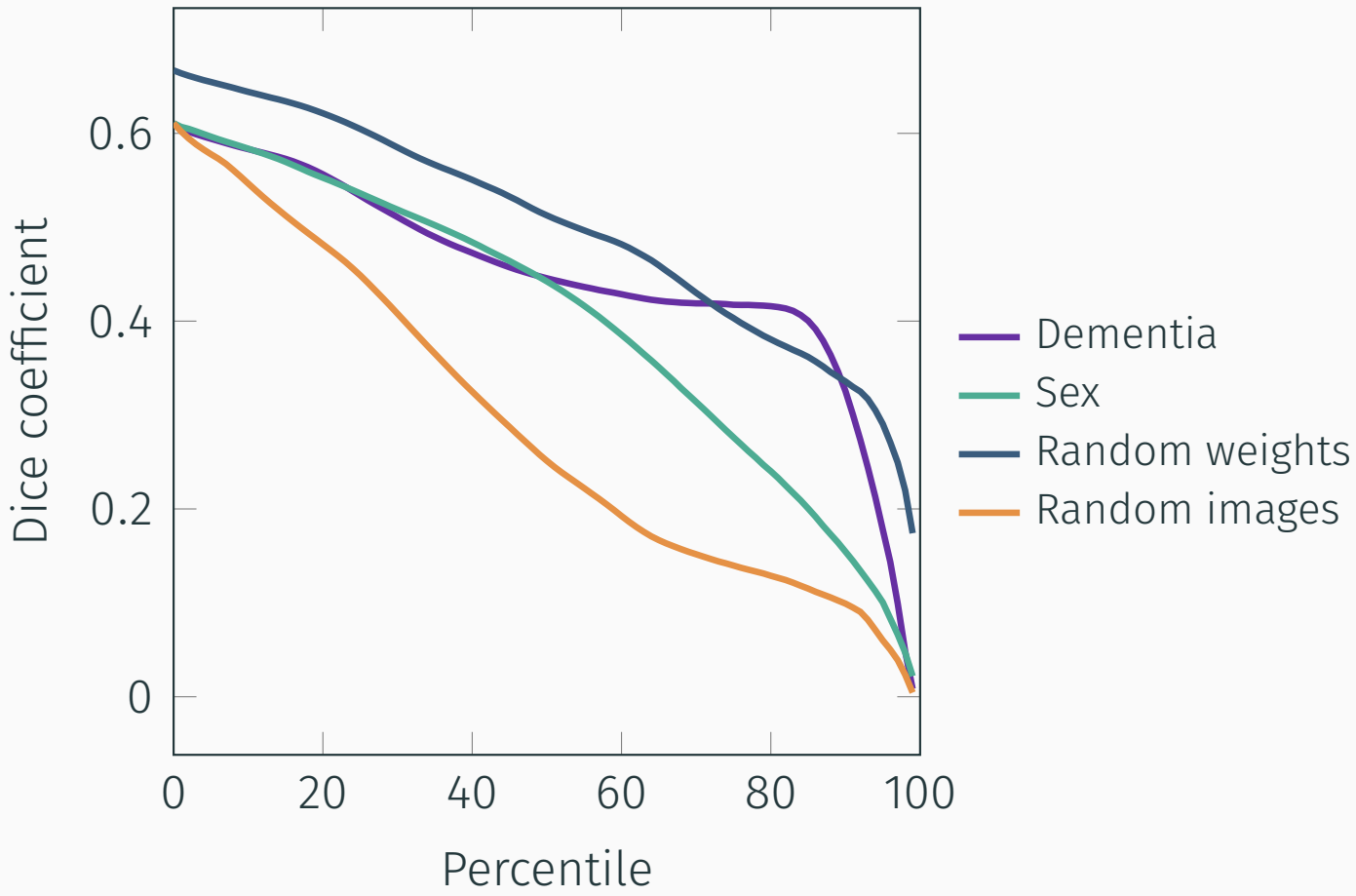
60th percentile



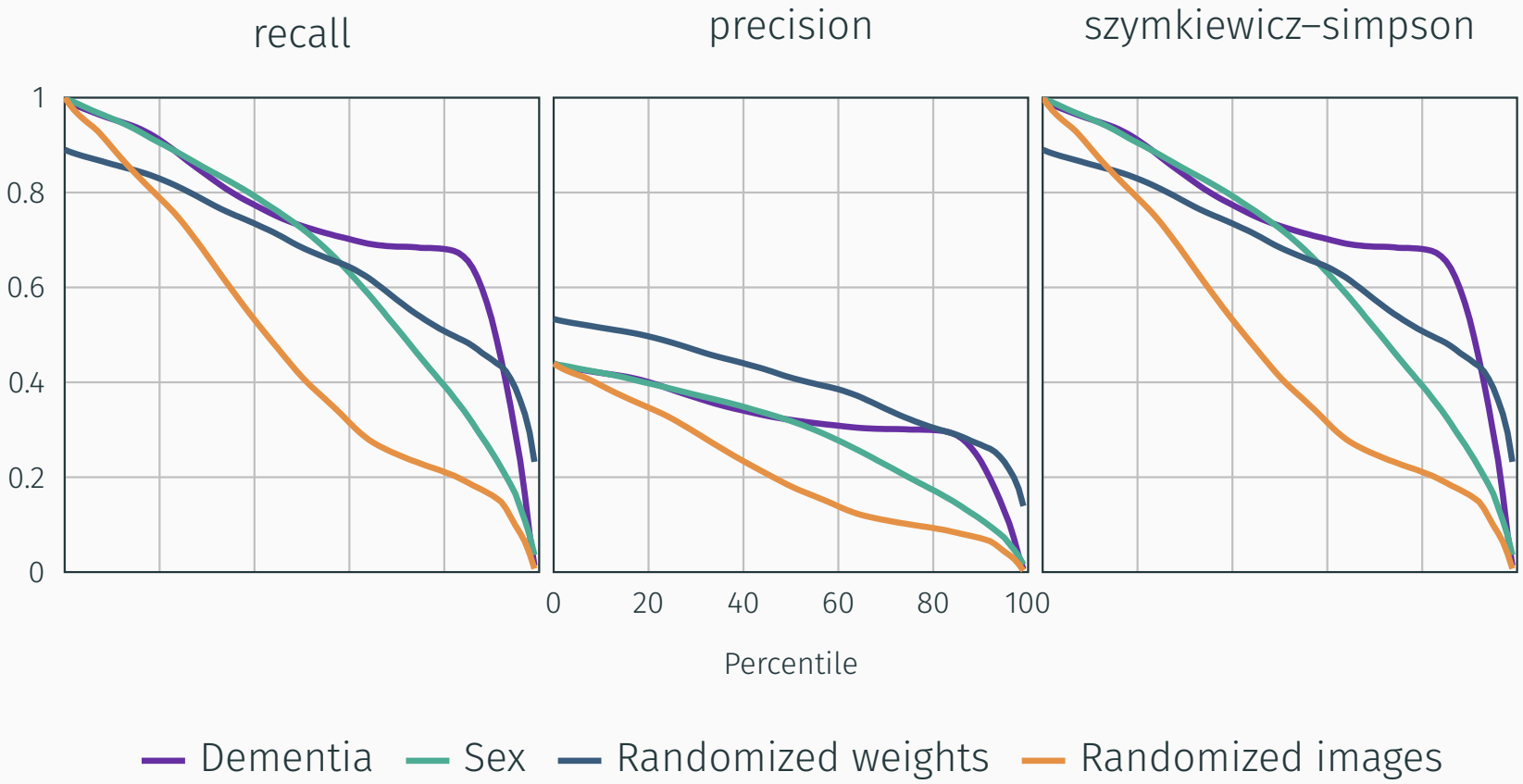
Dementia: Relevance maps



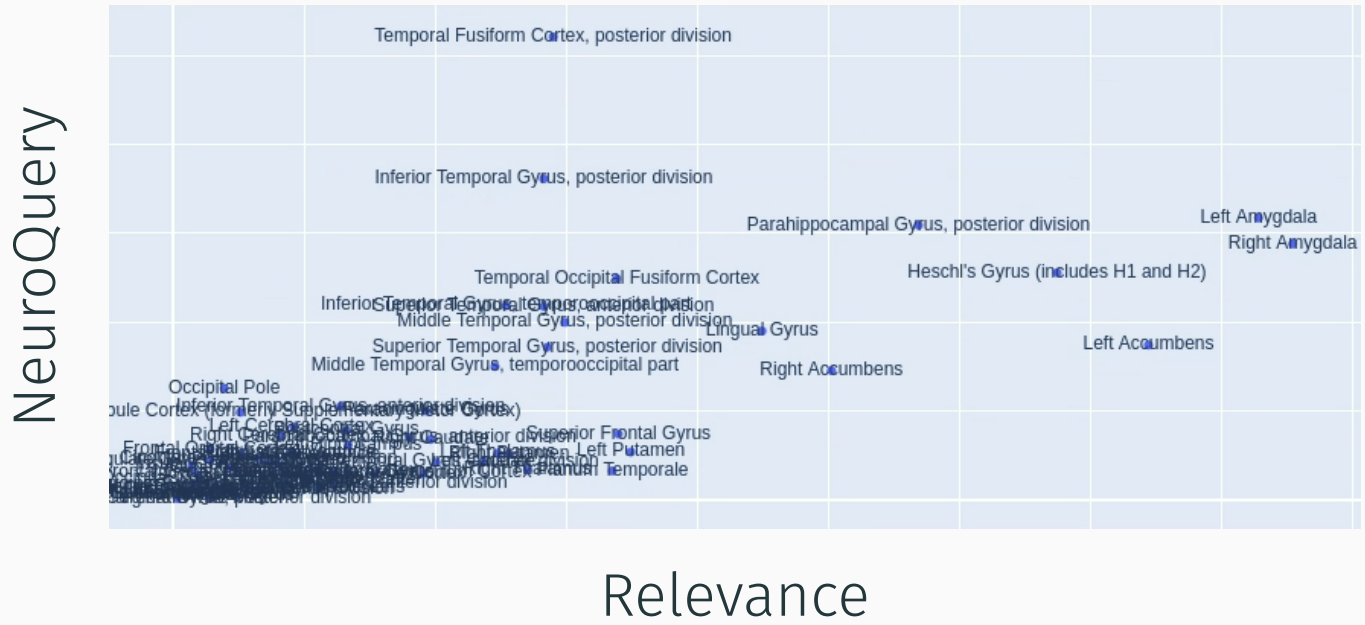
Dementia: Relevance maps



Dementia: Relevance maps

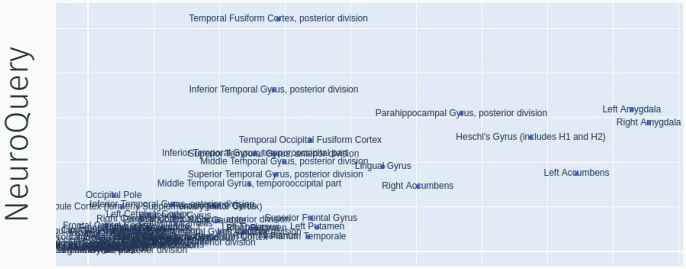


Dementia: Relevance maps

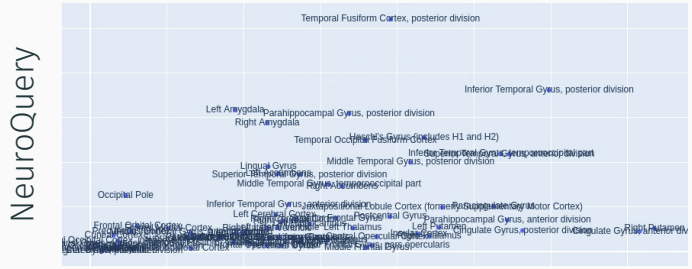


Dementia: Relevance maps

Dementia

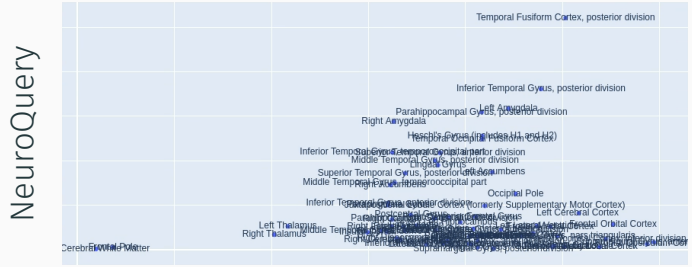


Sex



Randomized images

Randomized weights

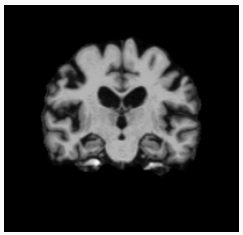


Dementia: Relevance maps

?

Dementia: Relevance maps

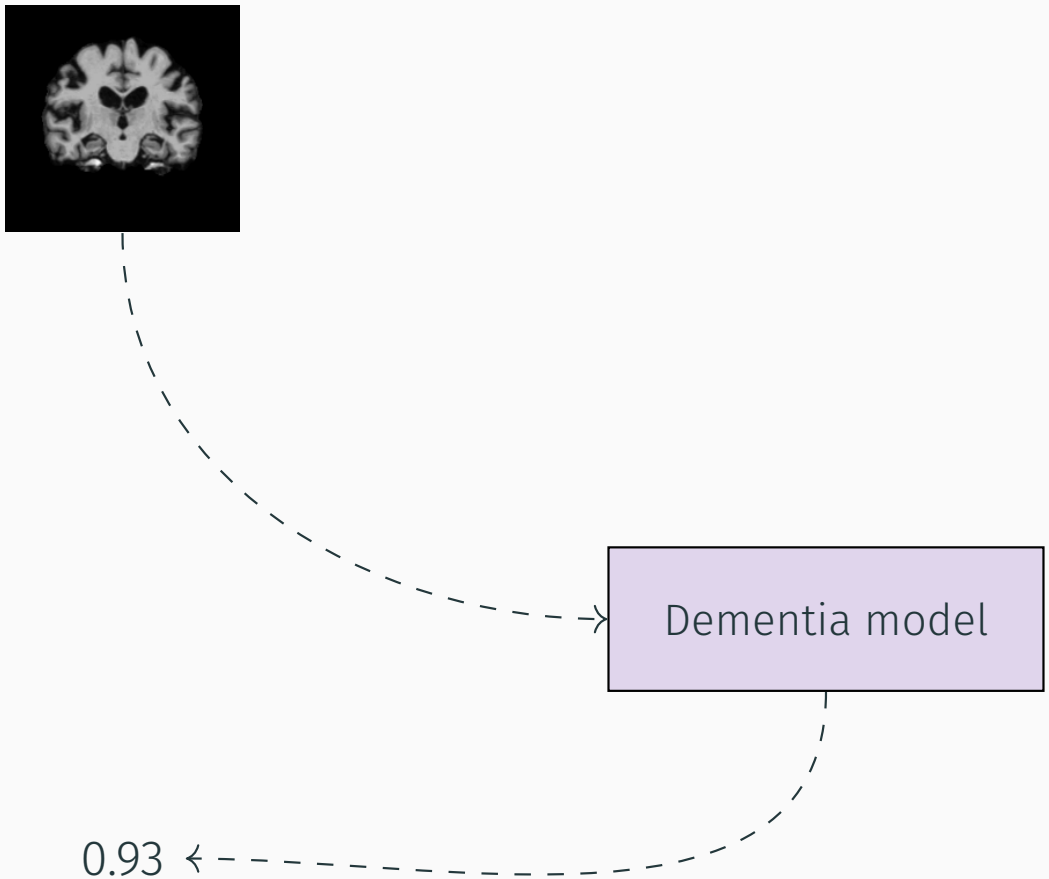
Iteration 0



Dementia model

Dementia: Relevance maps

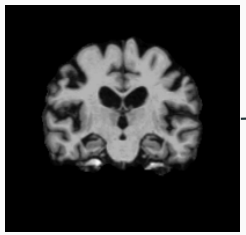
Iteration 0

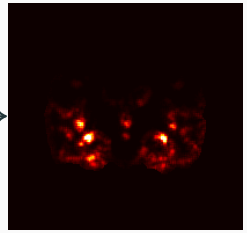


Dementia: Relevance maps

Iteration 0

Validation



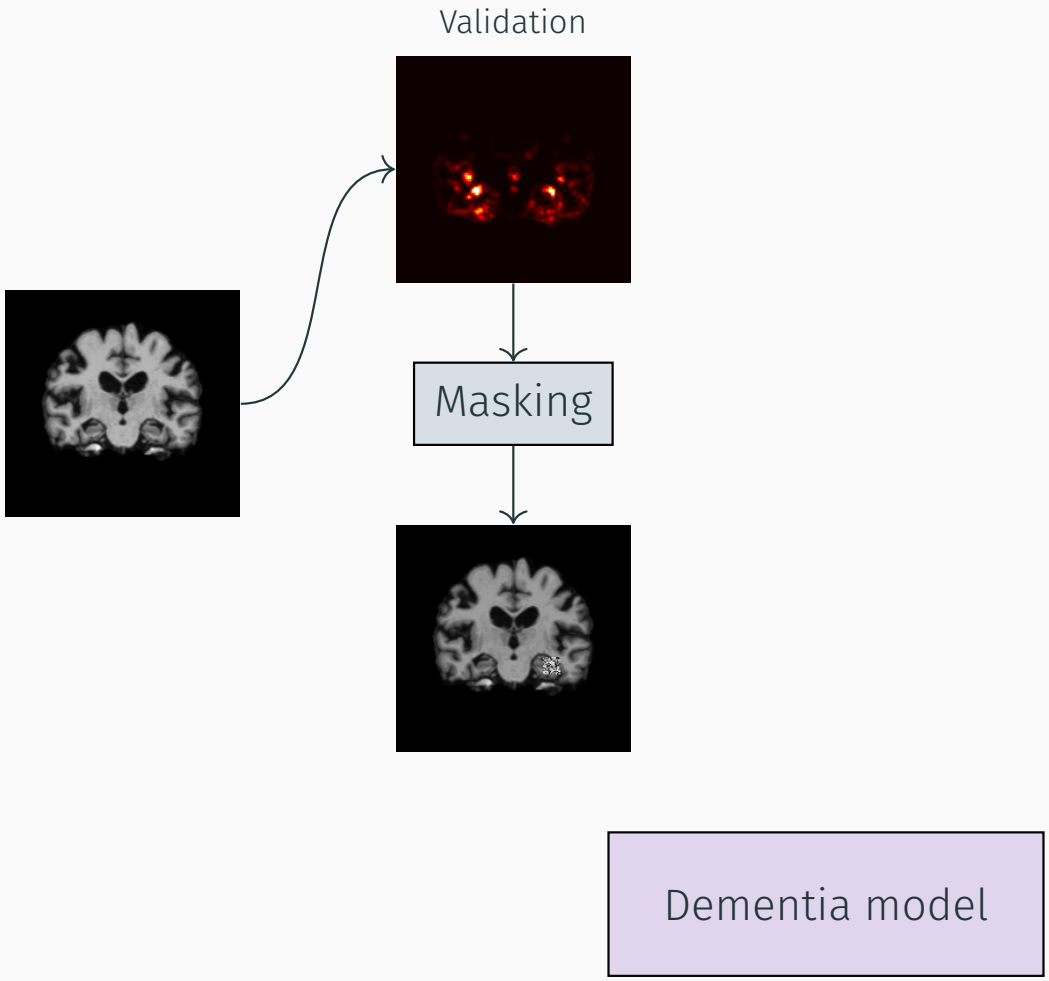


Dementia model

0.93

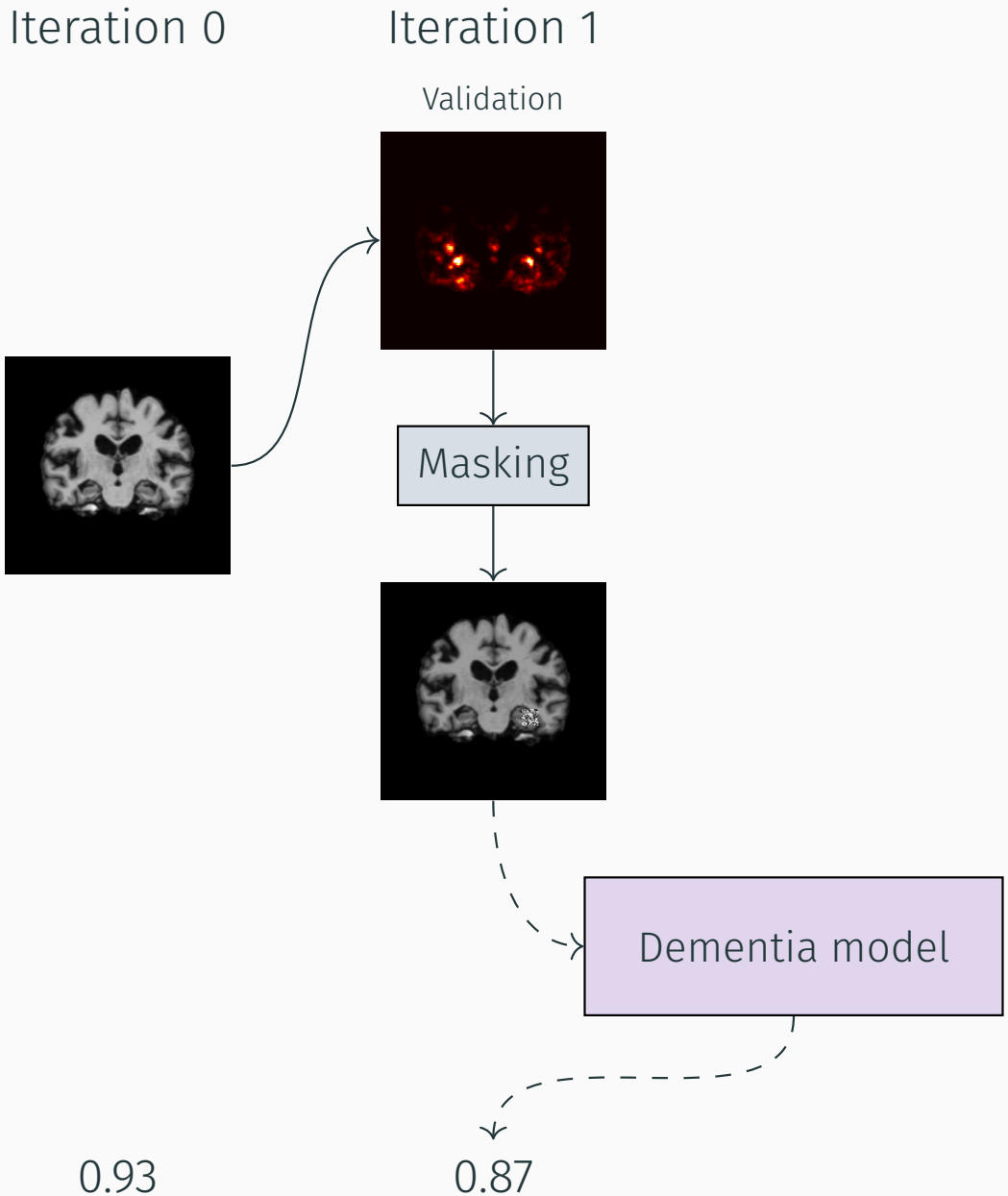
Dementia: Relevance maps

Iteration 0

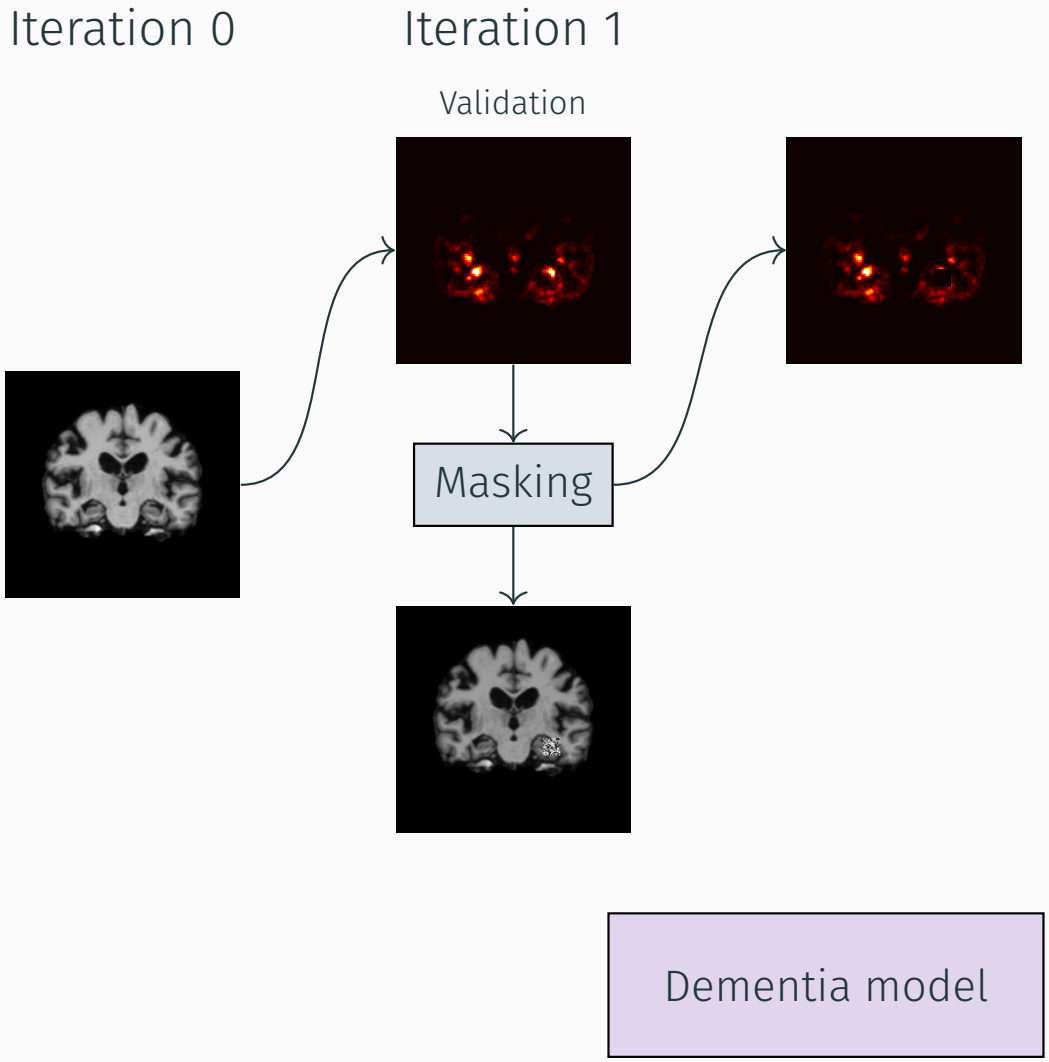


0.93

Dementia: Relevance maps



Dementia: Relevance maps



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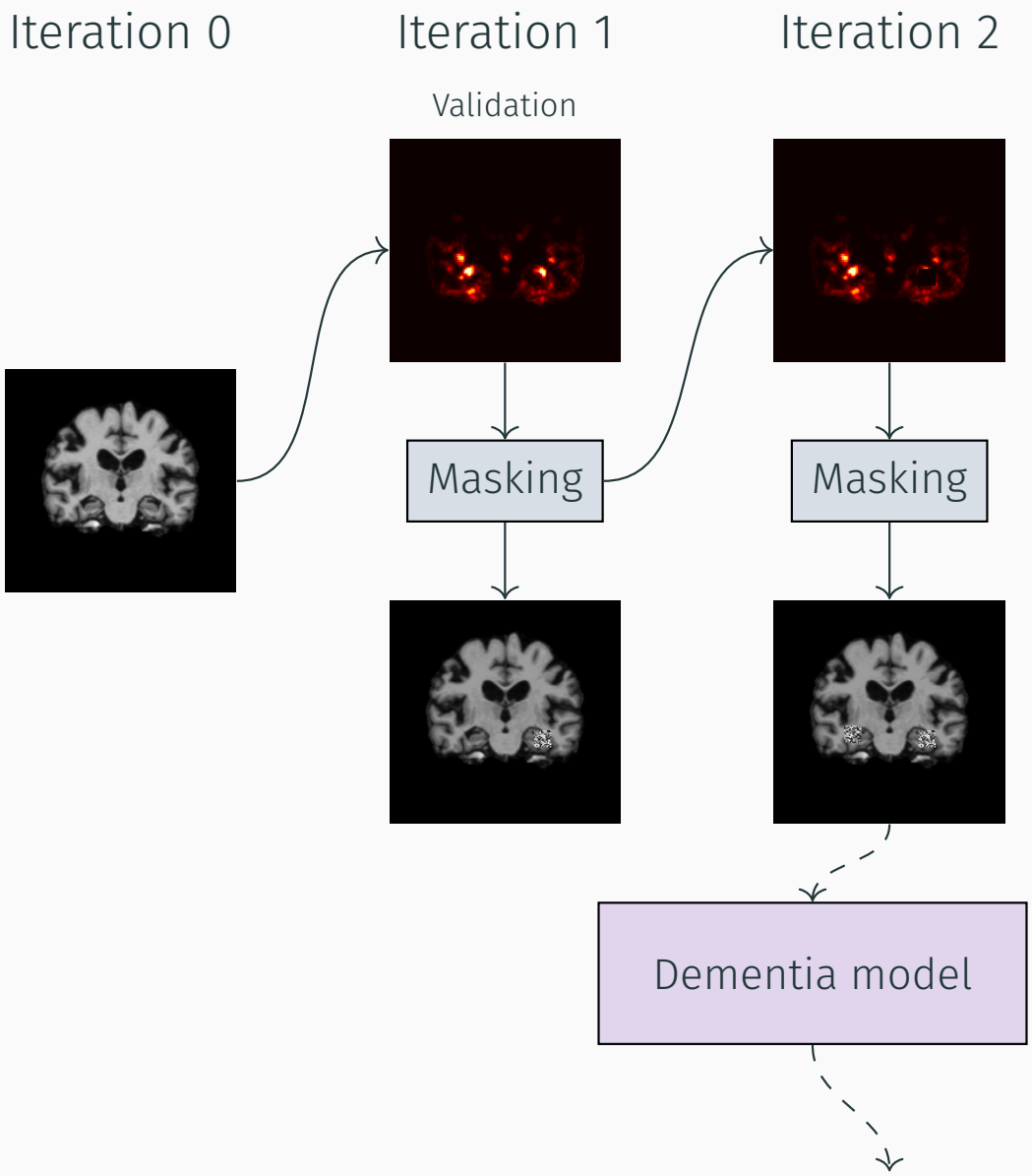
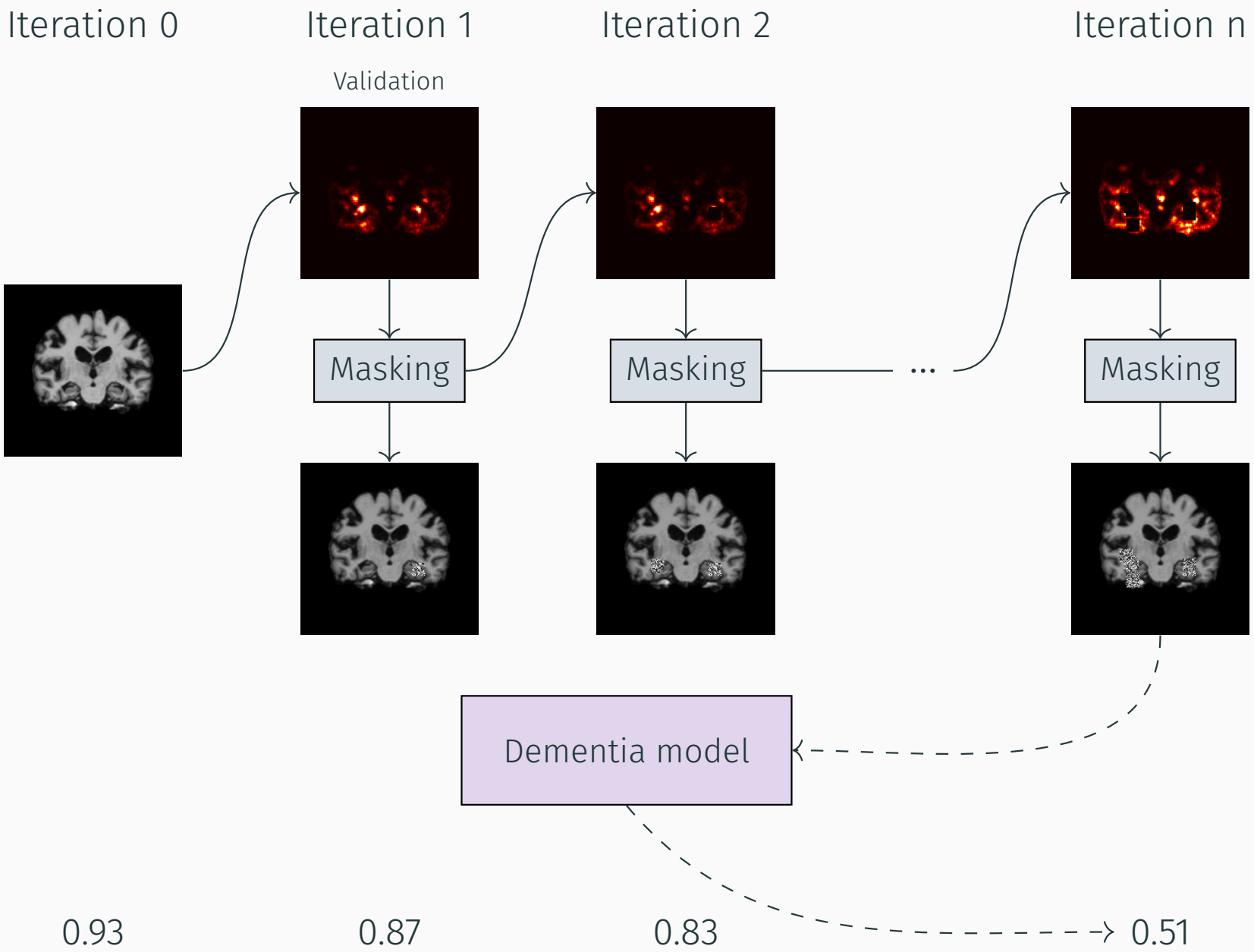
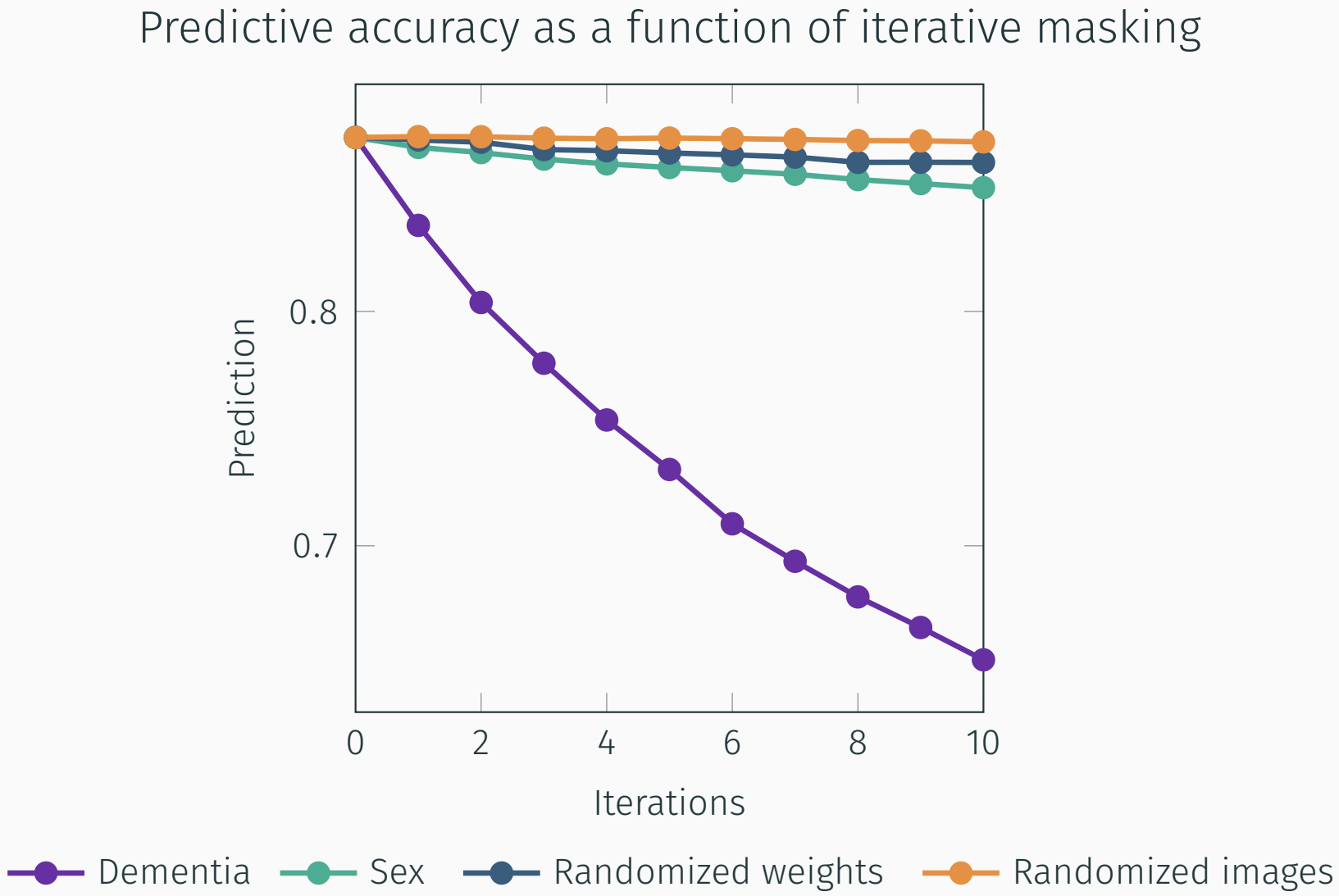


Dementia: Relevance maps



Dementia: Relevance maps



Botherations

- 4 validations:
  1. Spatial correlation: Seems qualitatively better then what is quantitatively shown.
  2. Region-wise correlation: Lacks a good ground truth, not quantitative.
  3. Individual-level specificity: ???
  4. Iterative predictions: Seems solid, but circular.
- How does the predictive performance affect the trust in the relevance maps?