

# Detecting individual-level deviations in brain morphology in MCI with explainable AI

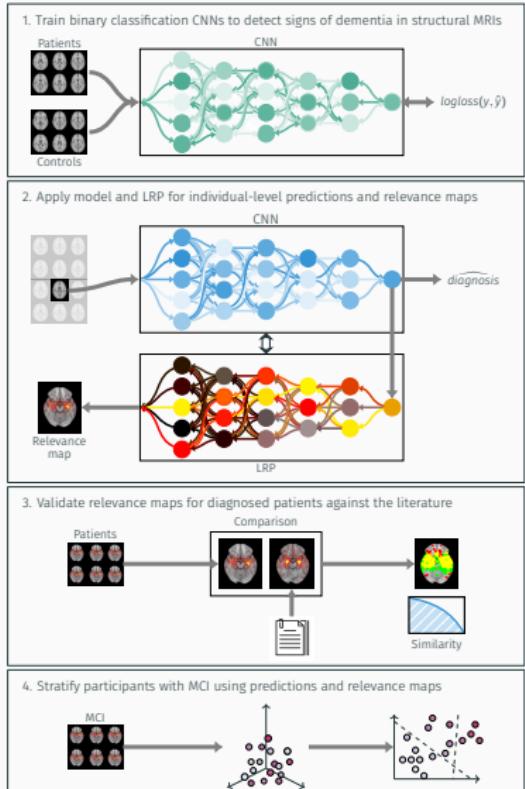
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Esten Høyland Leonardsen

15.09.22

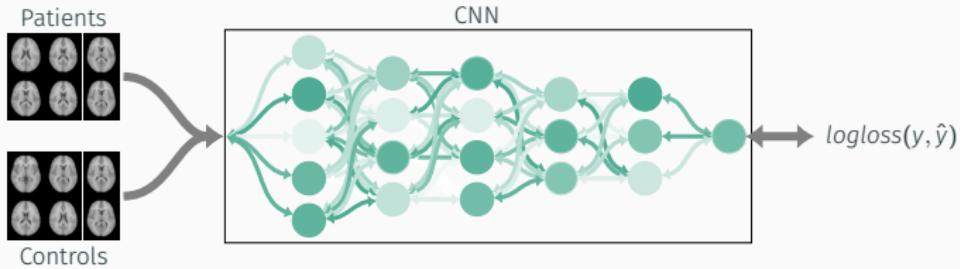
UiO:Life Science, University of Oslo

# Overview

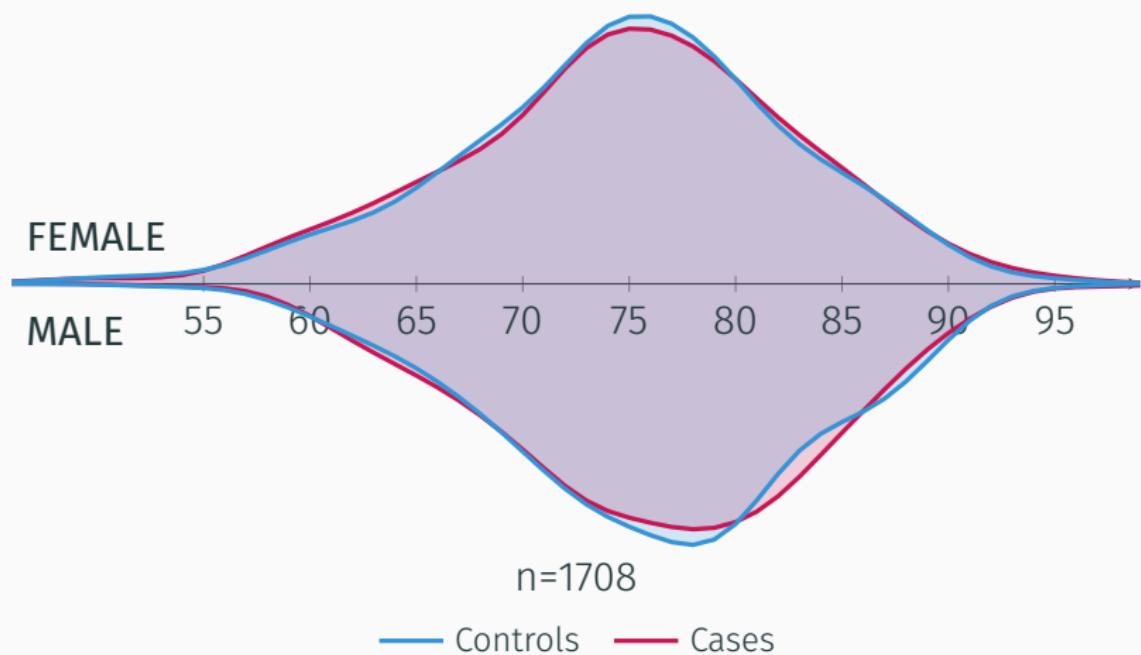


# Case-control predictions

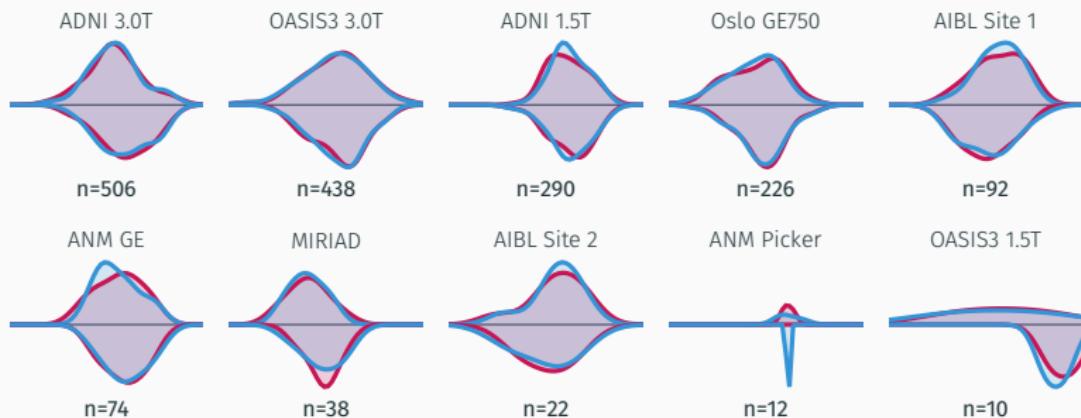
1. Train binary classification CNNs to detect signs of dementia in structural MRIs



## Case-control predictions



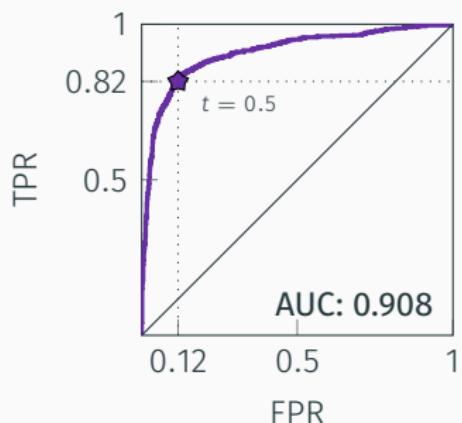
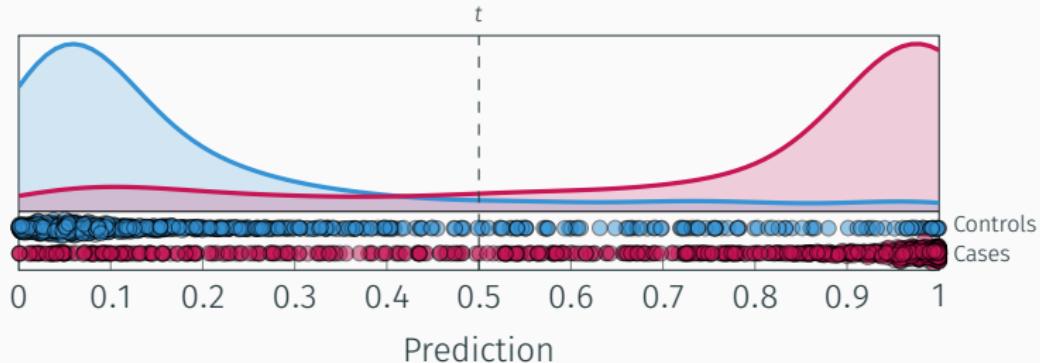
# Case-control predictions



# Case-control predictions

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

# Case-control predictions



Predicted

Observed	0	1
0	754	100
1	157	697

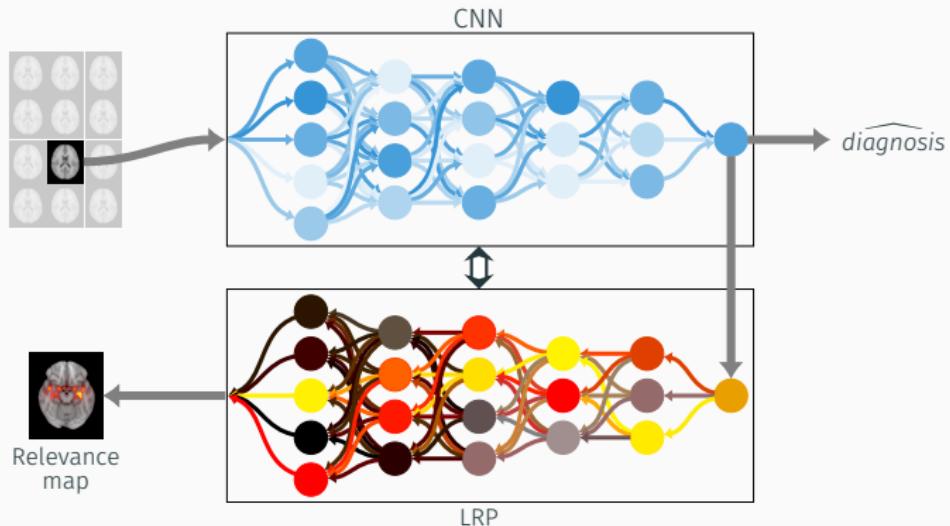
Accuracy: 84.95%

# Case-control predictions

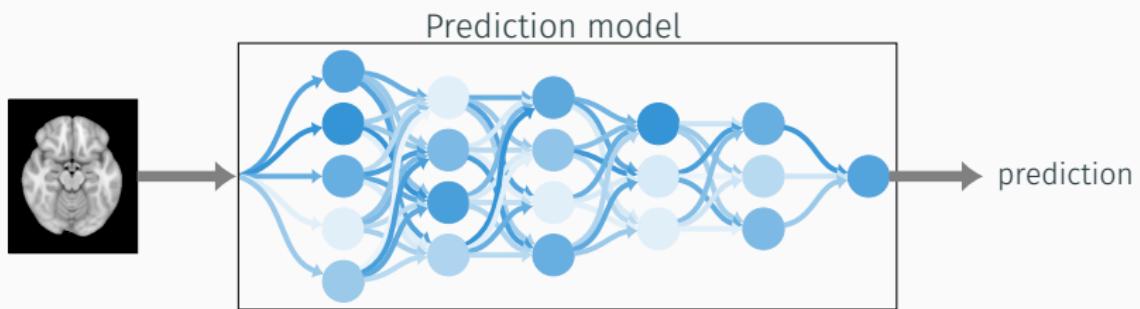
Sites	Size	AUC	Accuracy	Confusion Matrix	
ADNI 3.0T	506	0.942	90.11	237	16
				34	219
OASIS 3.0T	438	0.850	79.45	185	34
				56	163
ADNI 1.5T	290	0.944	87.93	125	20
				15	130
Oslo GE750	226	0.900	84.07	102	11
				25	88
AIBL Site 1	92	0.906	84.78	43	3
				11	35
ANM GE	74	0.848	72.97	26	11
				9	28
Miriad 1.5T	38	0.997	97.36	19	0
				1	18
AIBL Site 2	22	0.950	86.36	11	0
				3	8
OASIS 1.5T	12	0.666	58.33	3	3
				2	4
ANM Picker	10	0.76	70.00	3	2
				1	4

# Generating relevance maps

2. Apply model and LRP for individual-level predictions and relevance maps

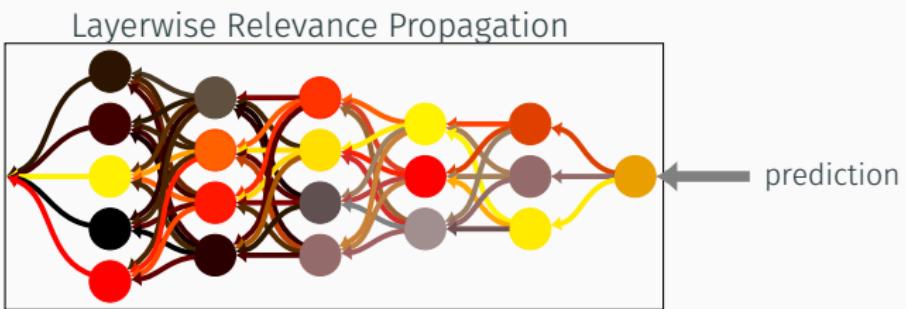


# Generating relevance maps



$$n_{i,j} = \sum_k n_{i-1,k} w_{k,j}$$

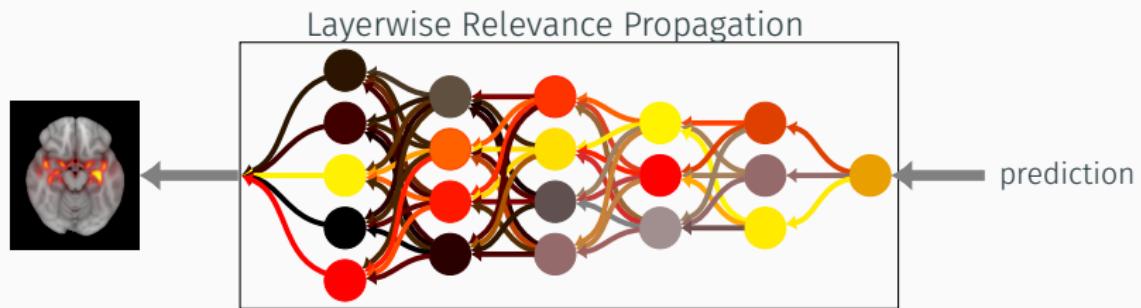
# Generating relevance maps



$$n_{i,j} = \sum_k n_{i-1,k} w_{k,j}$$

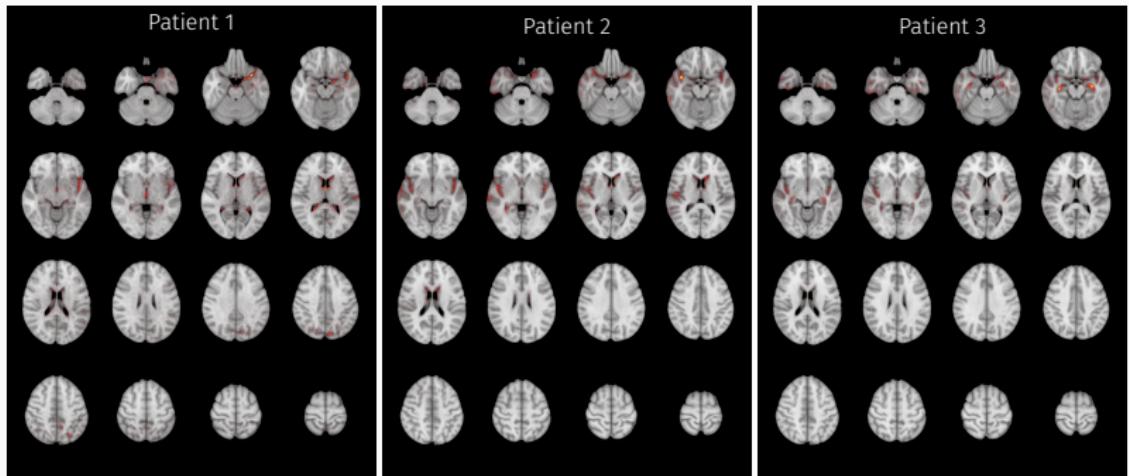
$$R_{i,j} = \sum_k \frac{a_j w_{j,k}}{\sum_l a_l w_{l,k}} R_{i+1,k}$$

# Generating relevance maps



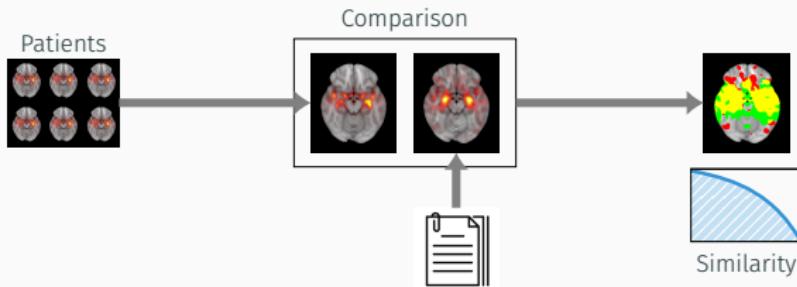
$$n_{i,j} = \sum_k n_{i-1,k} w_{k,j} \quad R_{i,j} = \sum_k \frac{a_j w_{j,k}}{\sum_l a_l w_{l,k}} R_{i+1,k}$$

# Generating relevance maps



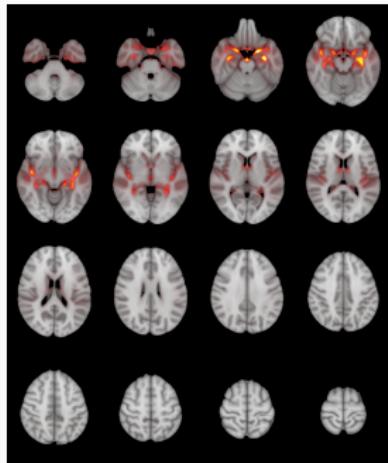
# Validating relevance maps in dementia patients

3. Validate relevance maps for diagnosed patients against the literature



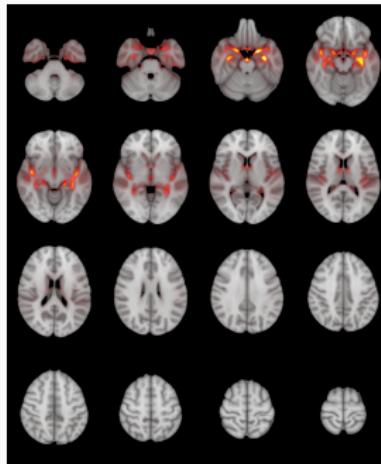
# Validating relevance maps in dementia patients

Average dementia patient

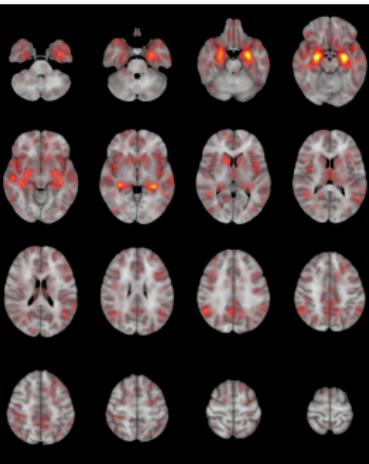


# Validating relevance maps in dementia patients

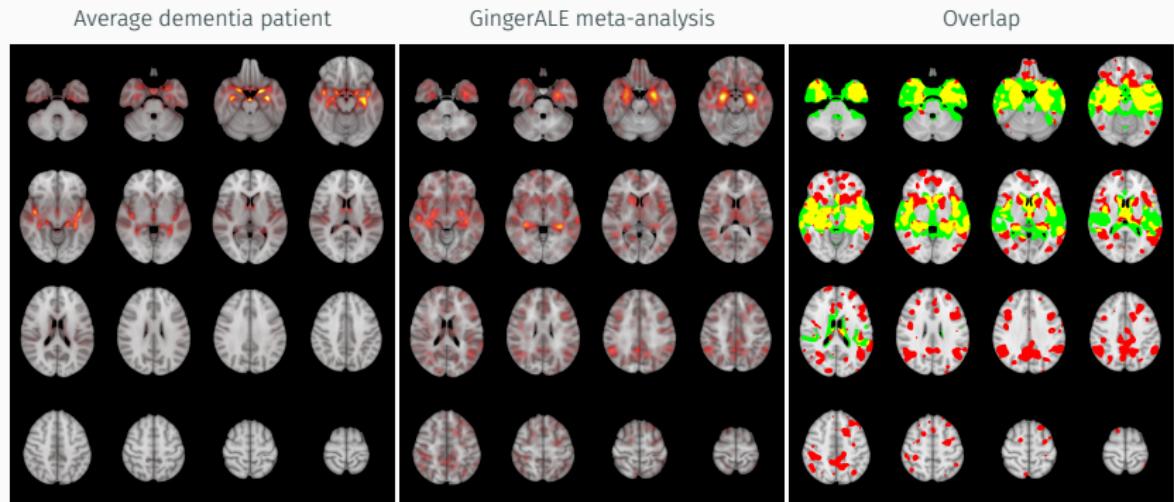
Average dementia patient



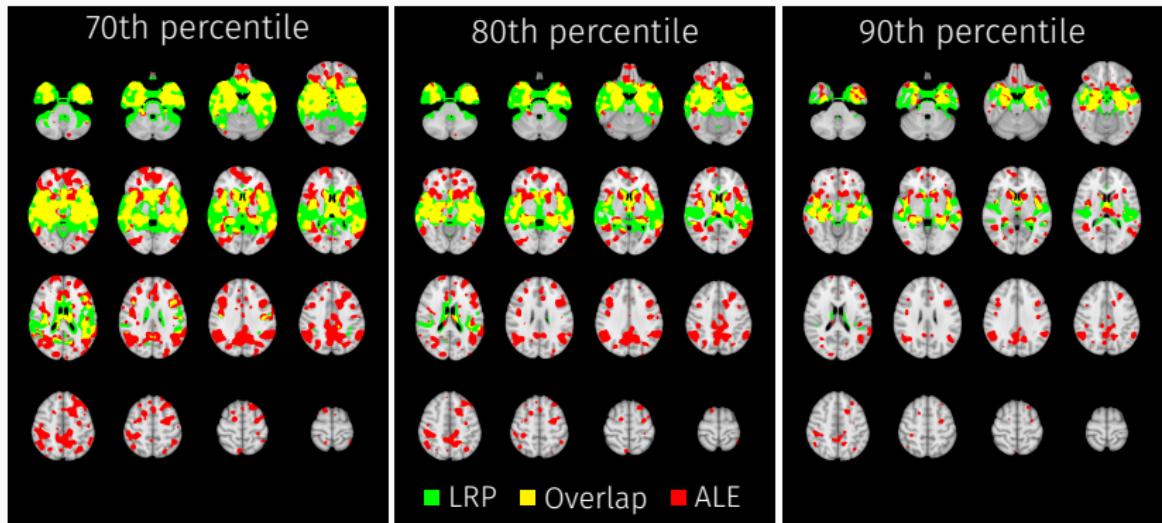
GingerALE meta-analysis



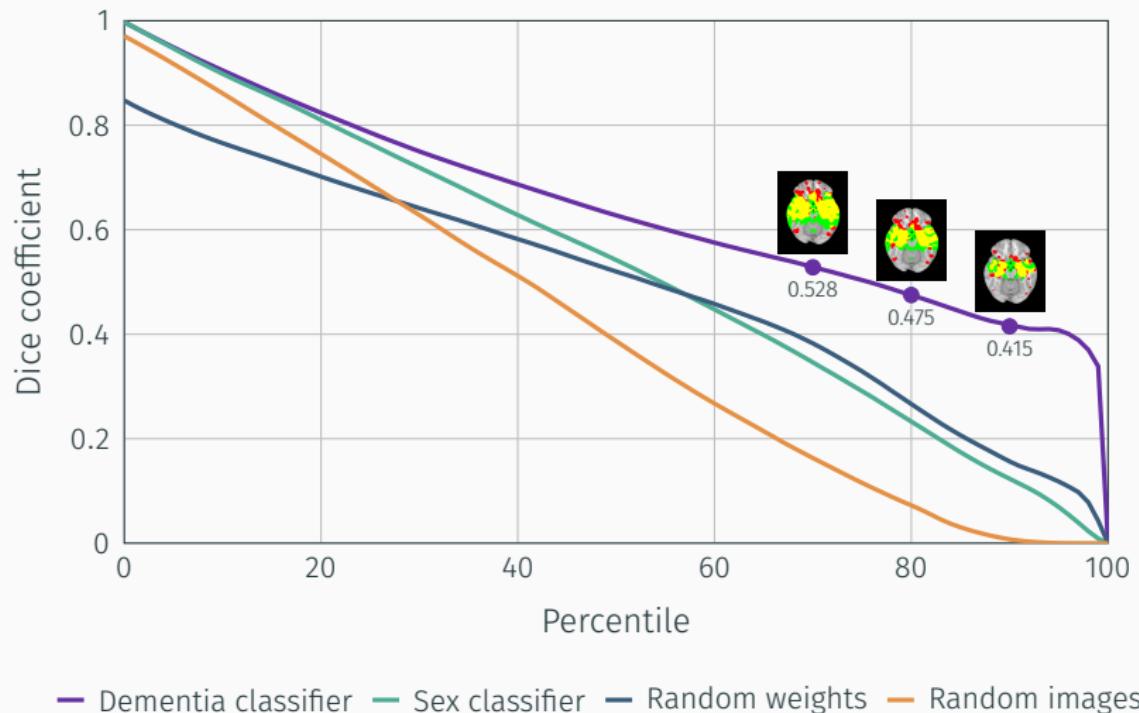
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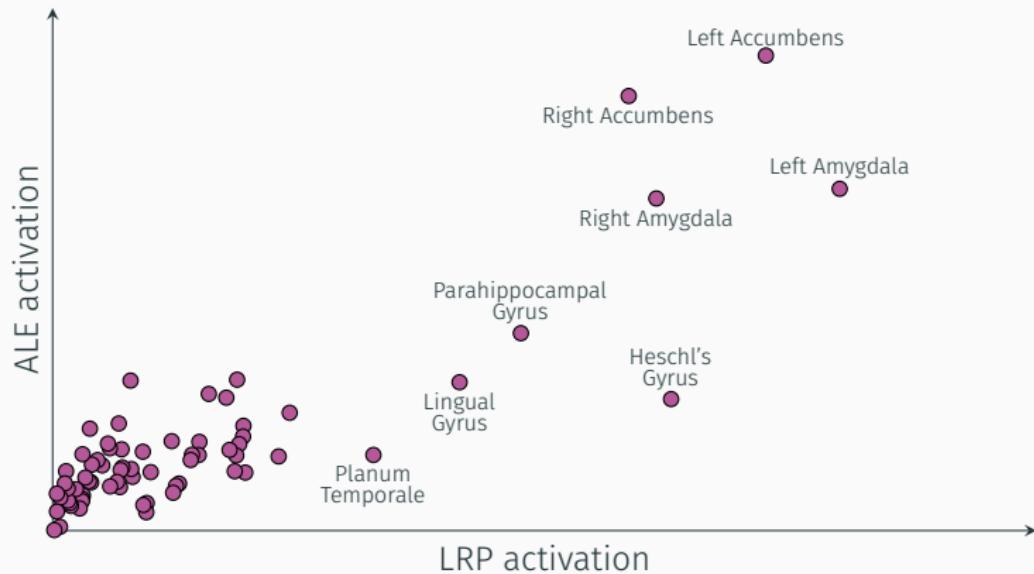
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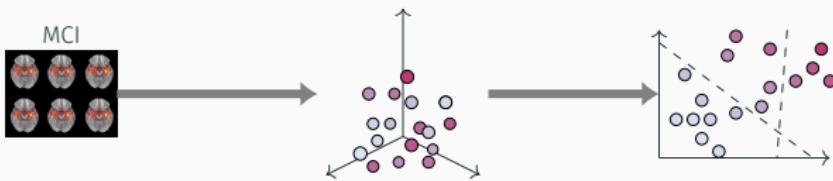


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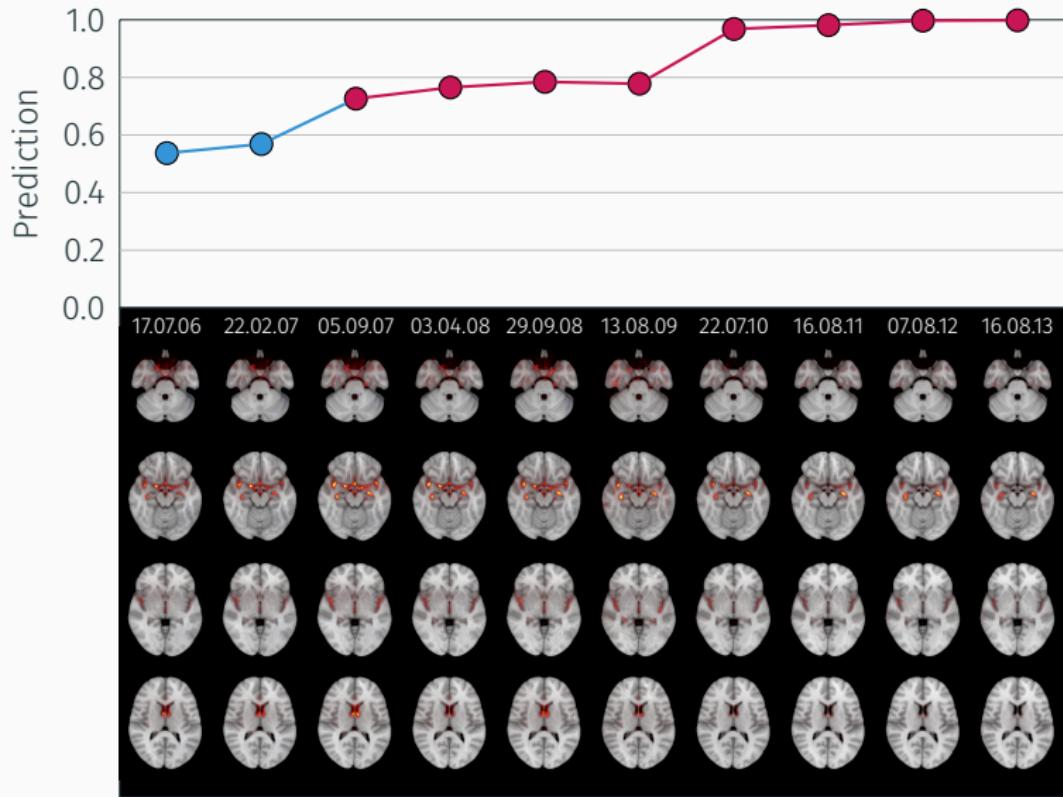


# Exploring relevance maps in MCI patients

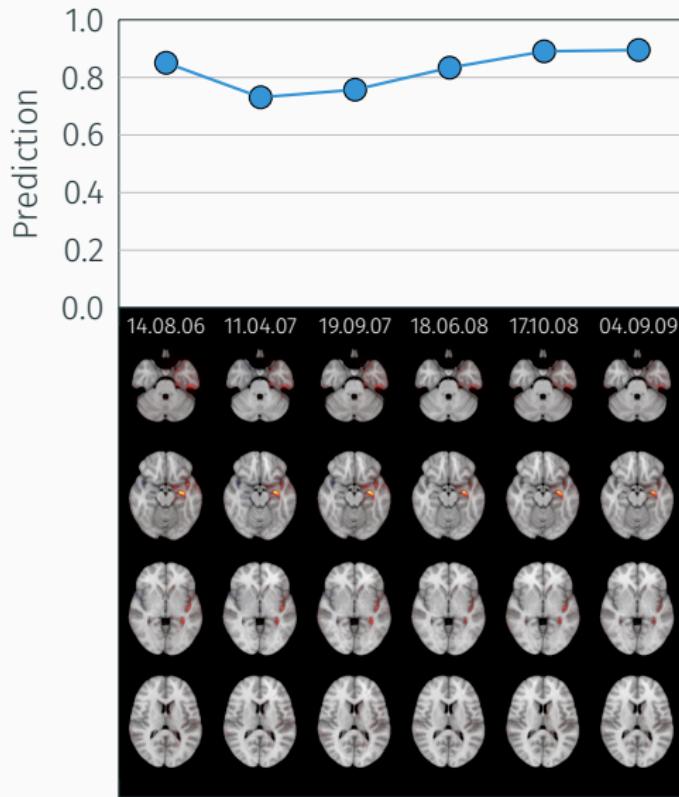
4. Stratify participants with MCI using predictions and relevance maps



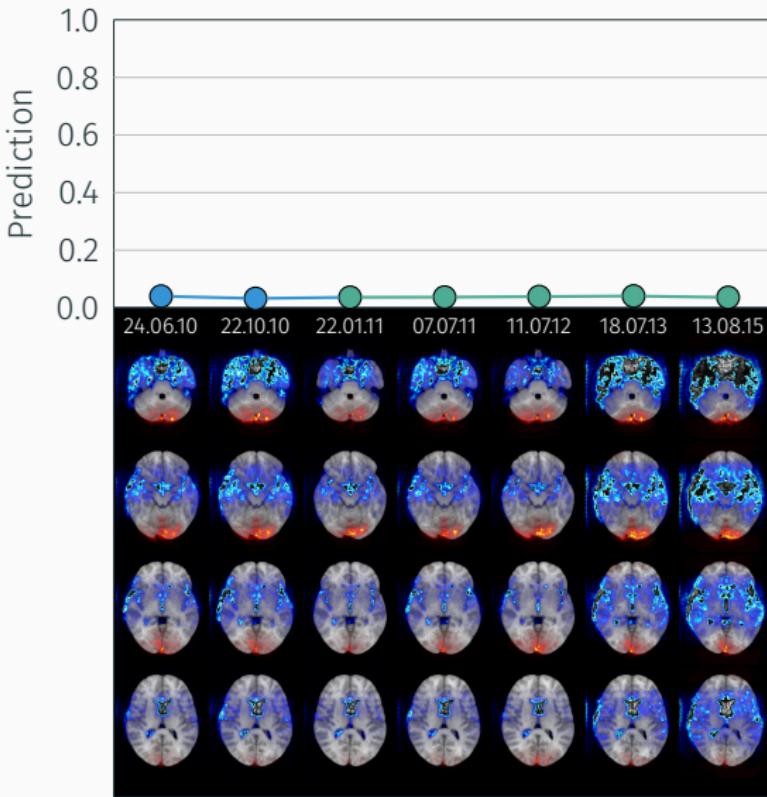
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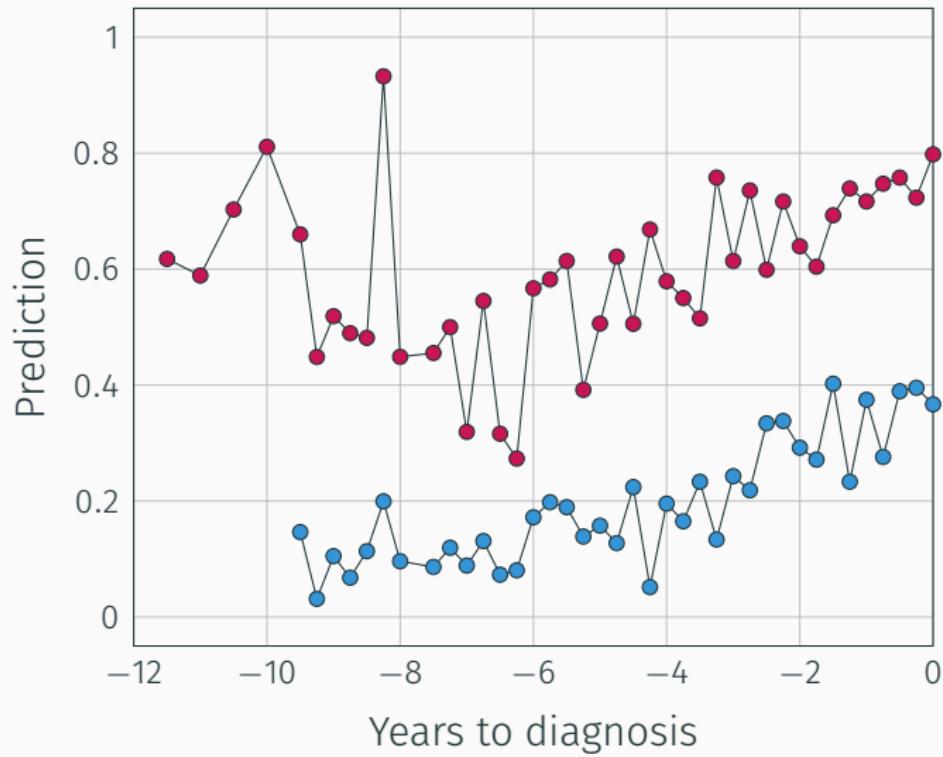
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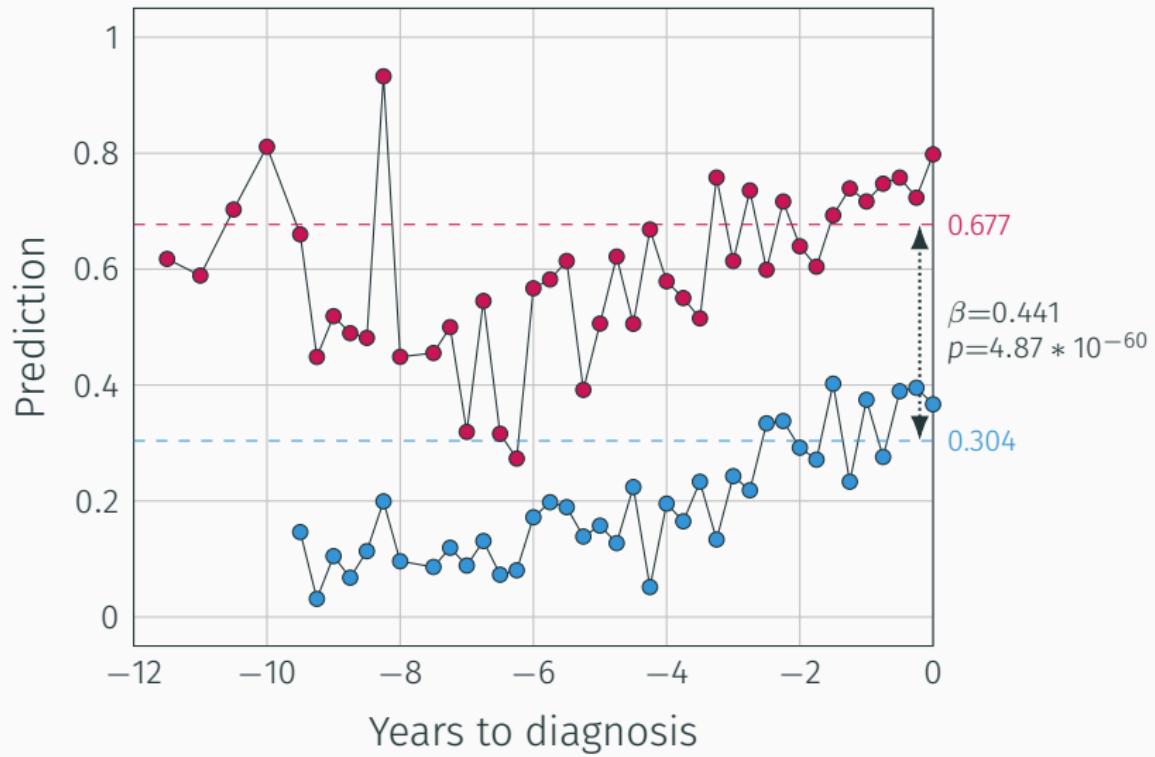
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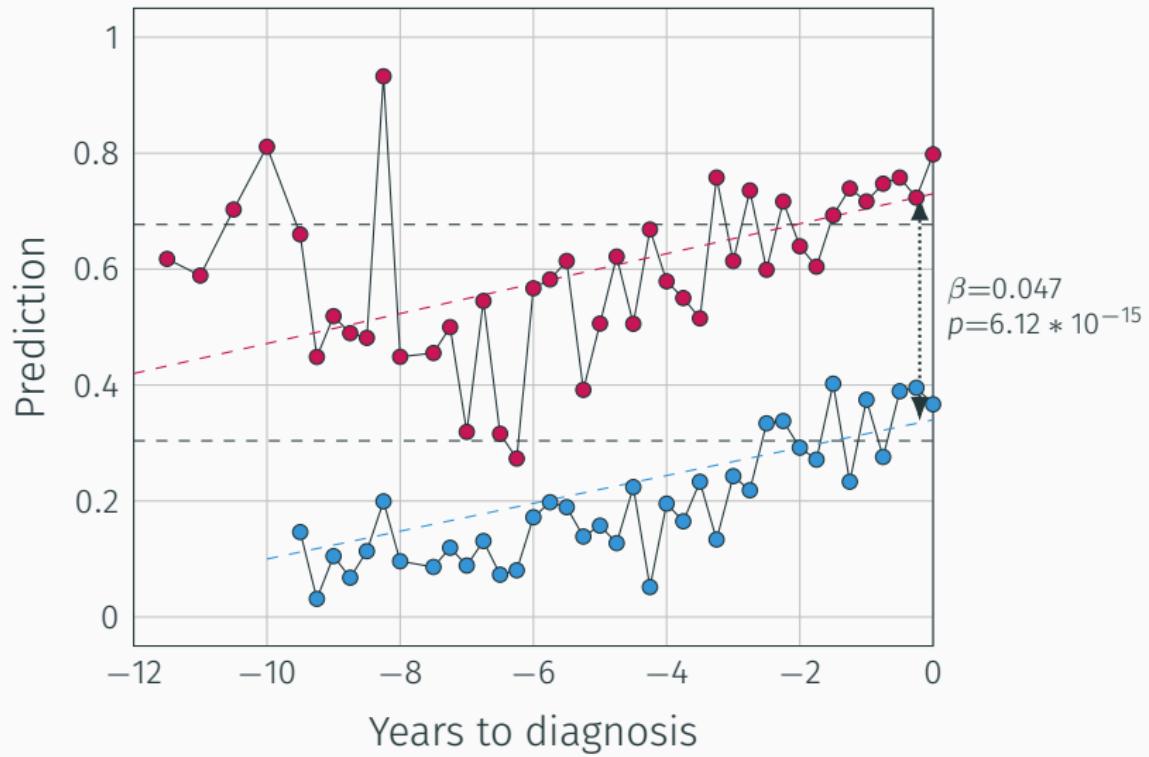
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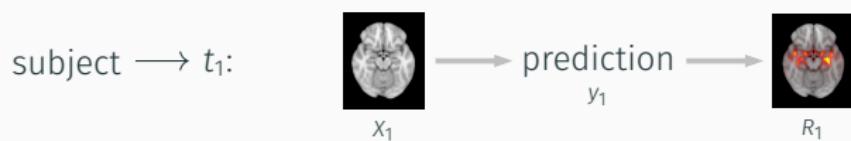
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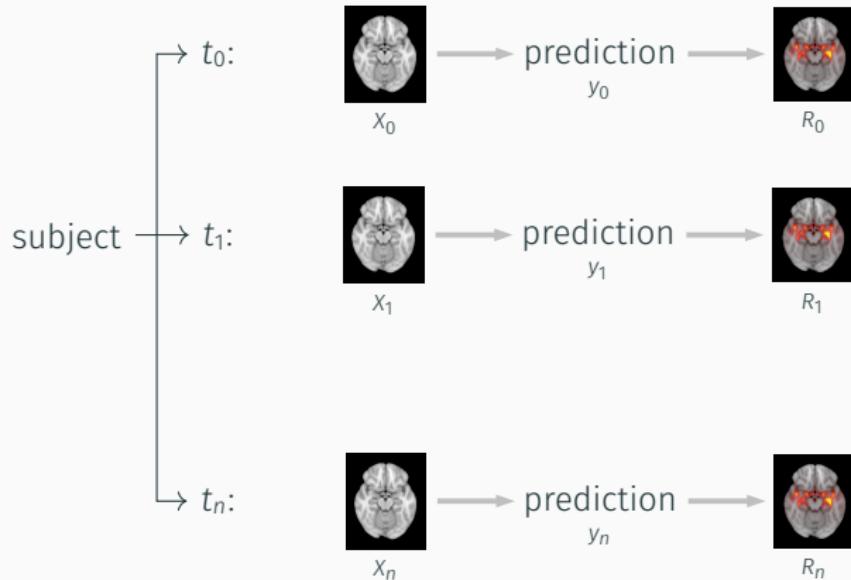
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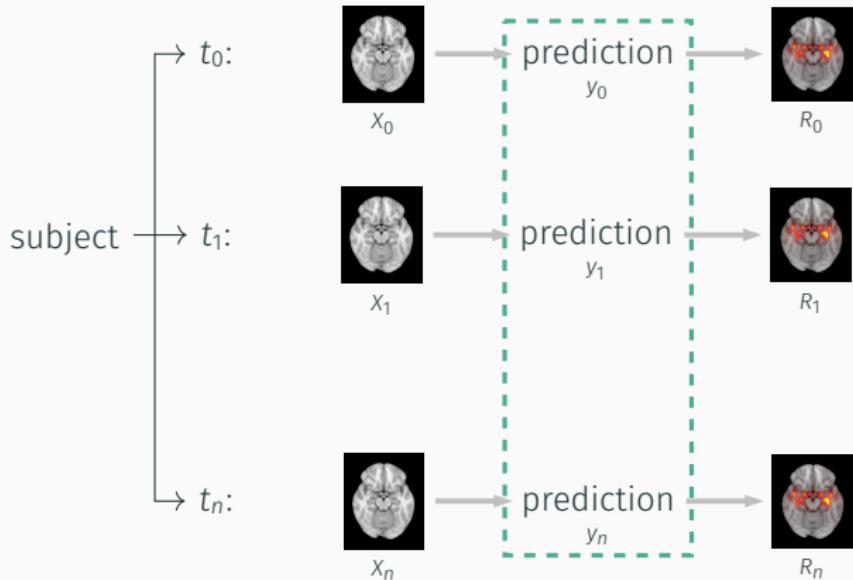
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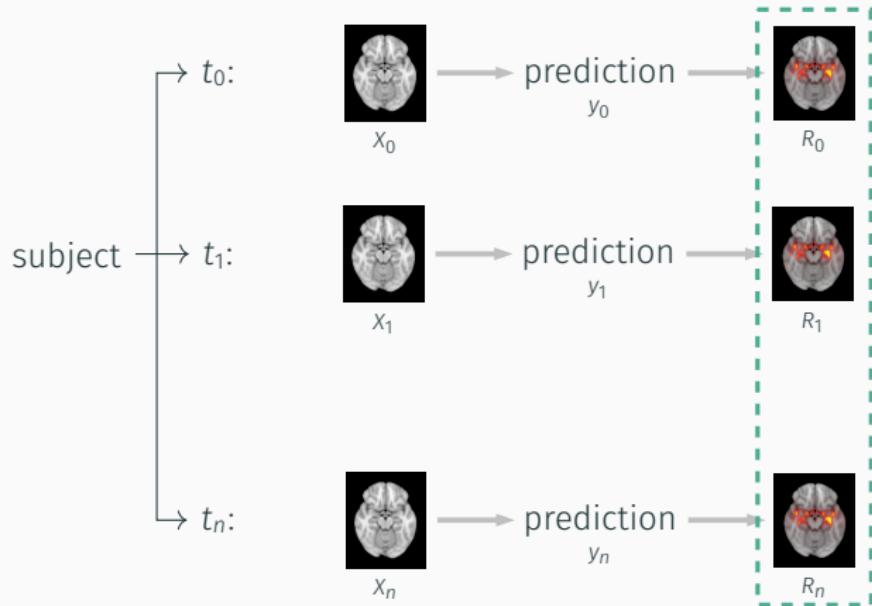
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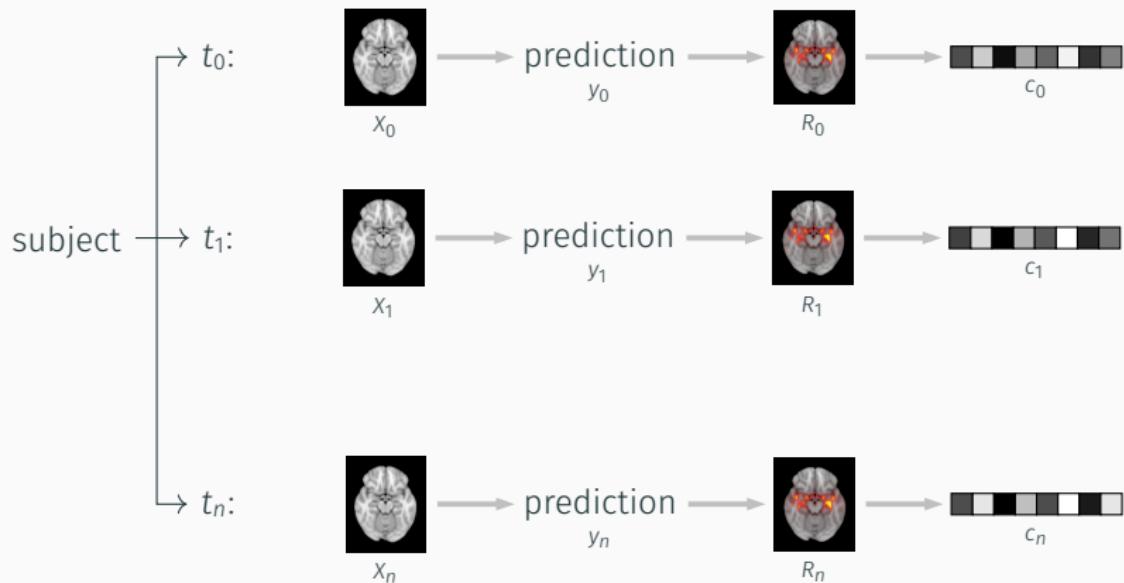
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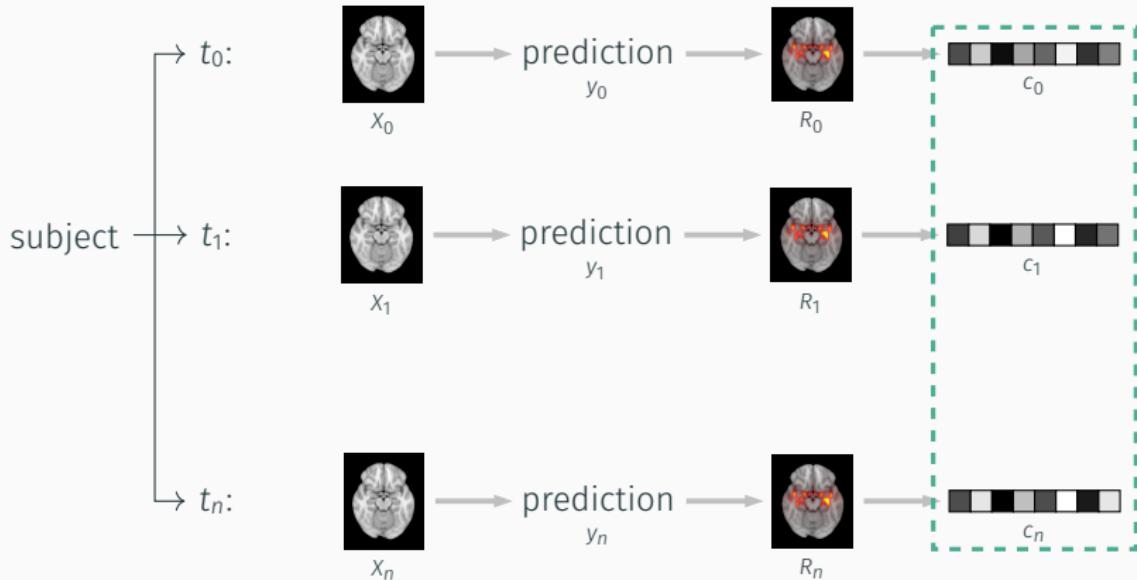
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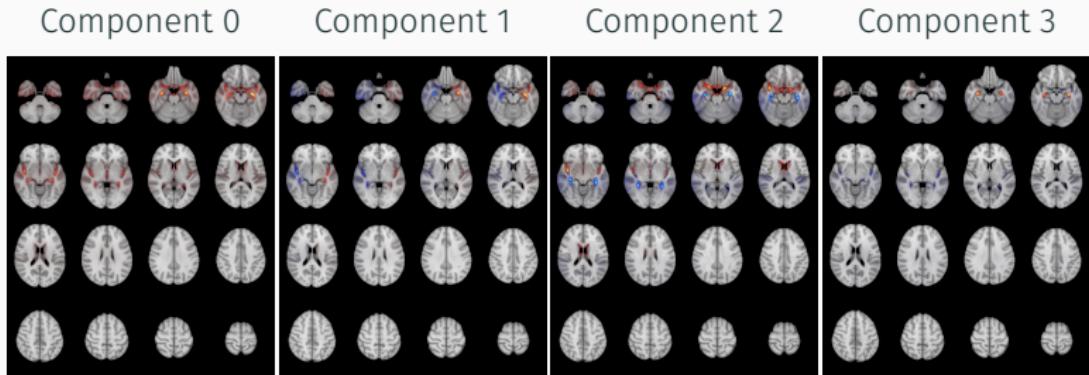
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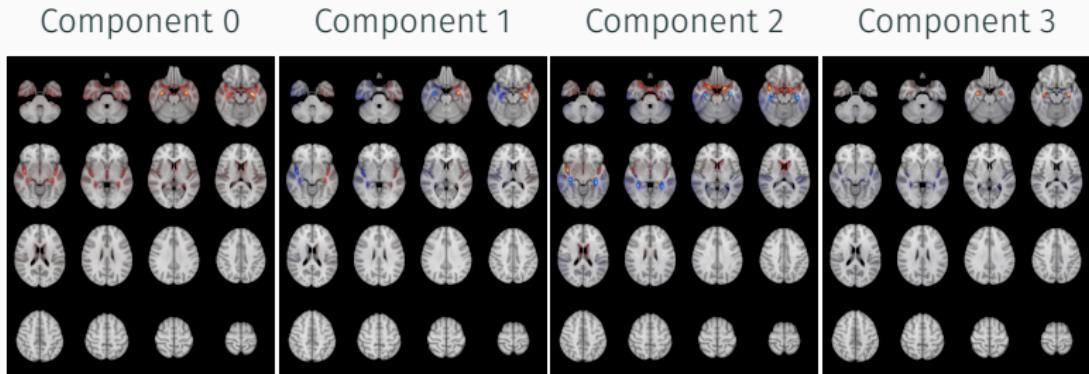
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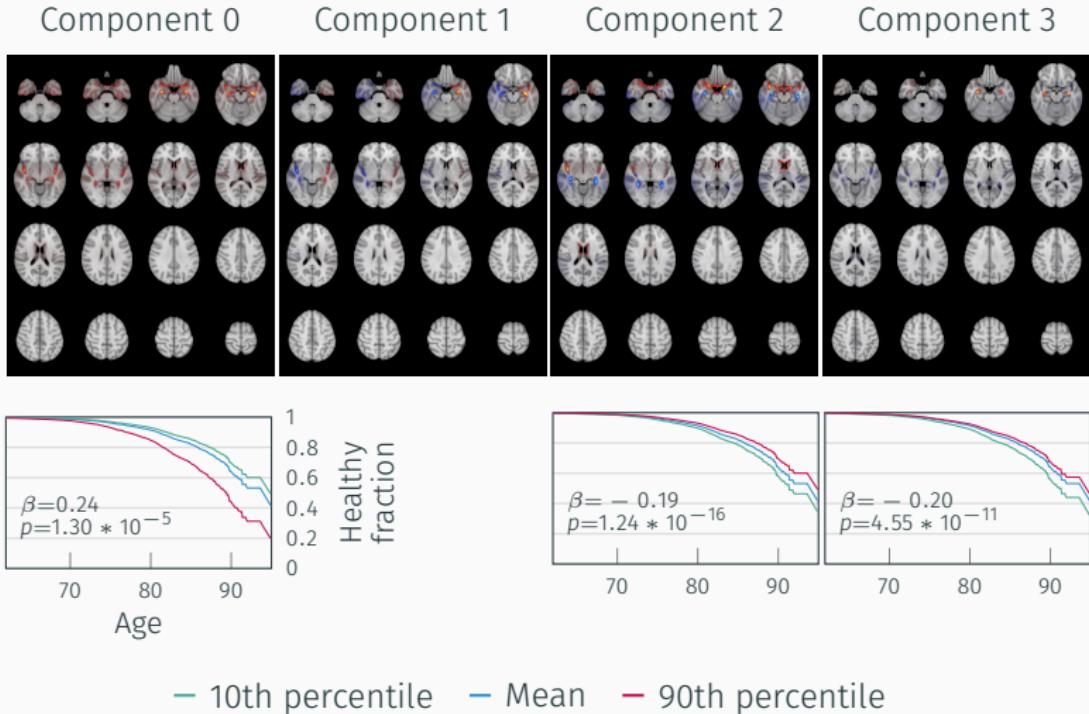


$$p=1.19 * 10^{-15}$$

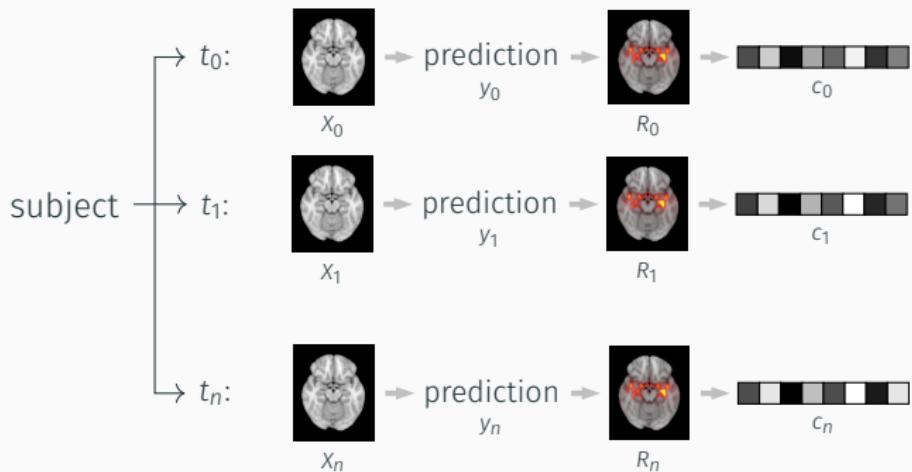
$$p=6.62 * 10^{-4}$$

$$p=1.06 * 10^{-5}$$

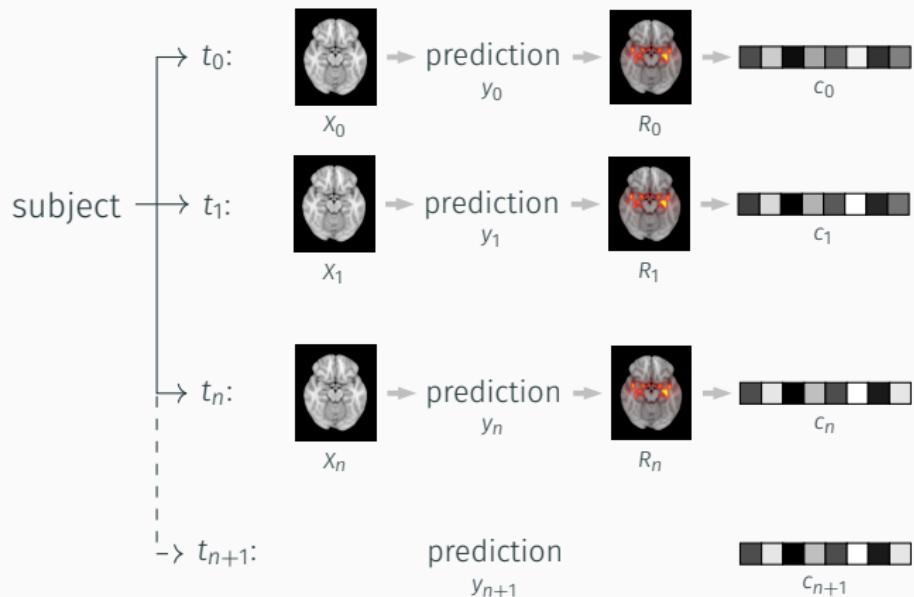
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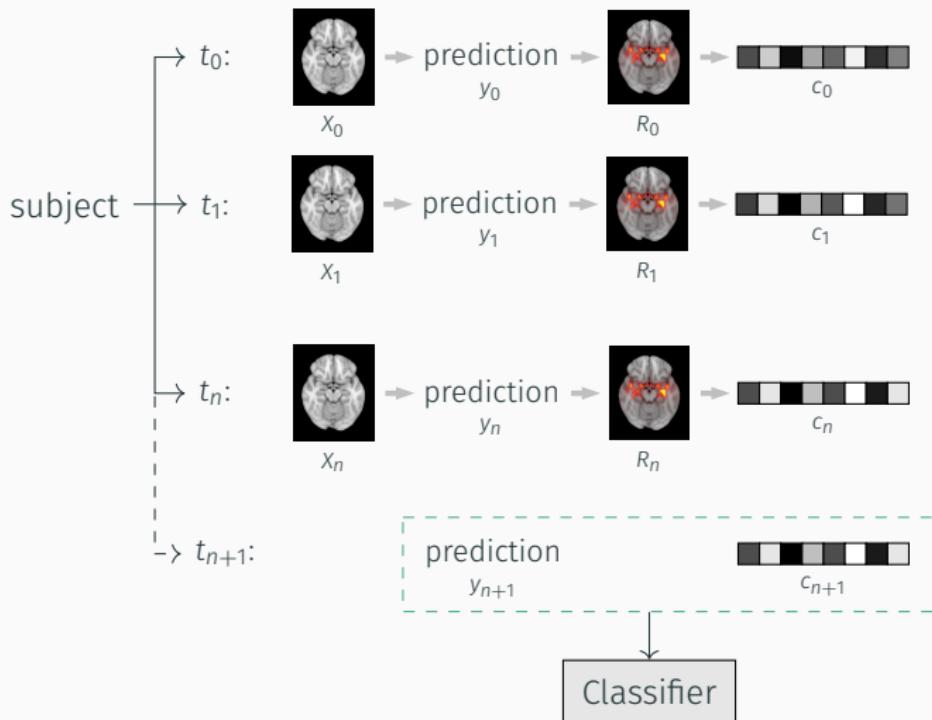
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Covariates	AUC	Balanced accuracy
age+sex+age:sex	0.515	50.40%
age+sex+age:sex+y <sub>n</sub>	0.719	59.12%
age+sex+age:sex+ŷ <sub>n+1</sub> +ŷ̂ <sub>n+1</sub>	0.822	75.06%

Prediction of  $diagnosis_{n+1}$

# Exploring relevance maps in MCI patients

*"There is an X% chance the patient will progress into dementia by date XX.YY.ZZZZ based on existing pathology in brain regions A, B and C, and an expected increase/decrease of pathology in regions D and E."*