

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

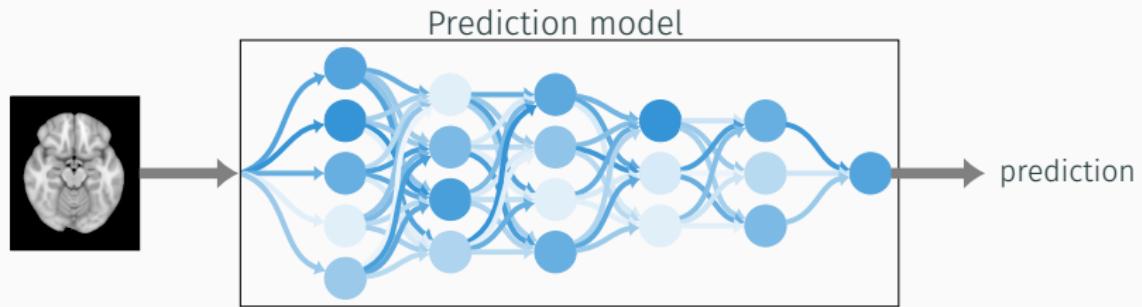
Esten Høyland Leonardsen

20.10.22

UiO:Life Science, University of Oslo

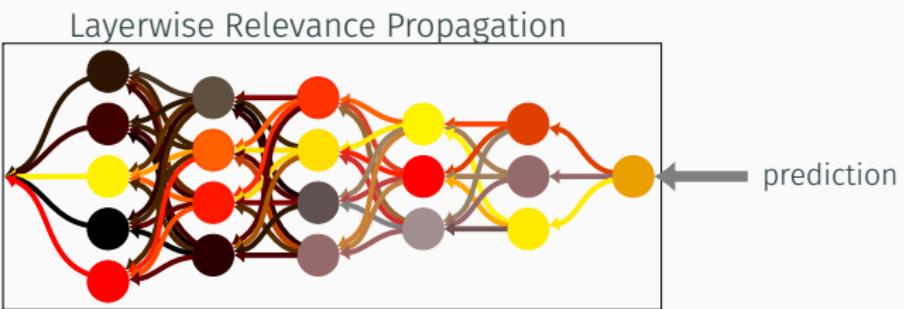


Layerwise Relevance Propagation



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

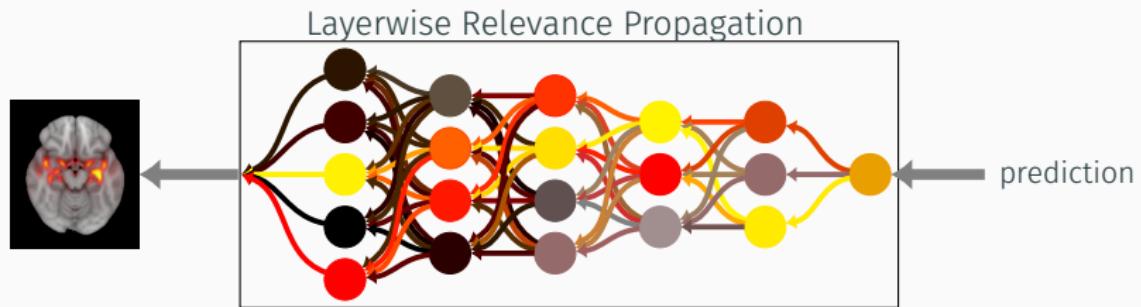
Layerwise Relevance Propagation



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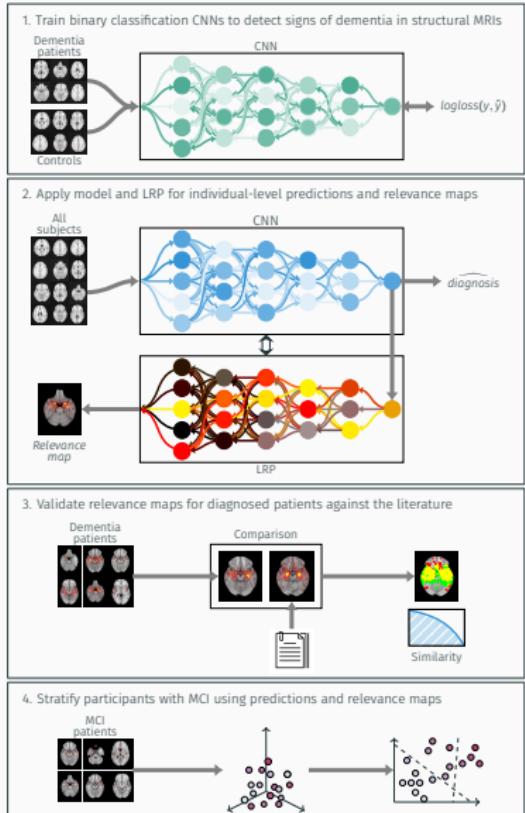
$$R_{i,j} = \sum_k \frac{a_j w_{j,k}}{\sum_l a_l w_{l,k}} R_{i+1,k}$$

Layerwise Relevance Propagation



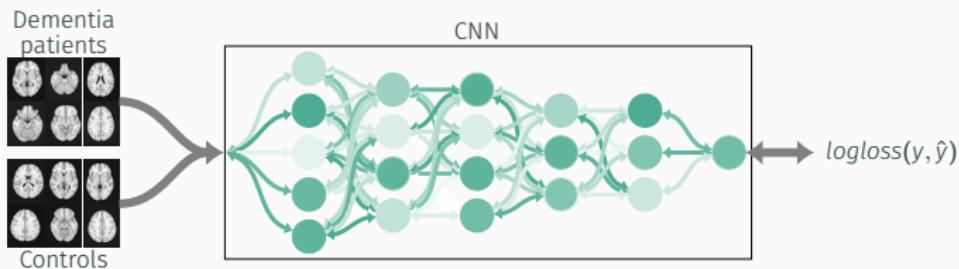
$$n_{i,j} = \sum_k n_{i-1,k} w_{k,j} \quad R_{i,j} = \sum_k \frac{a_j w_{j,k}}{\sum_l a_l w_{l,k}} R_{i+1,k}$$

Overview

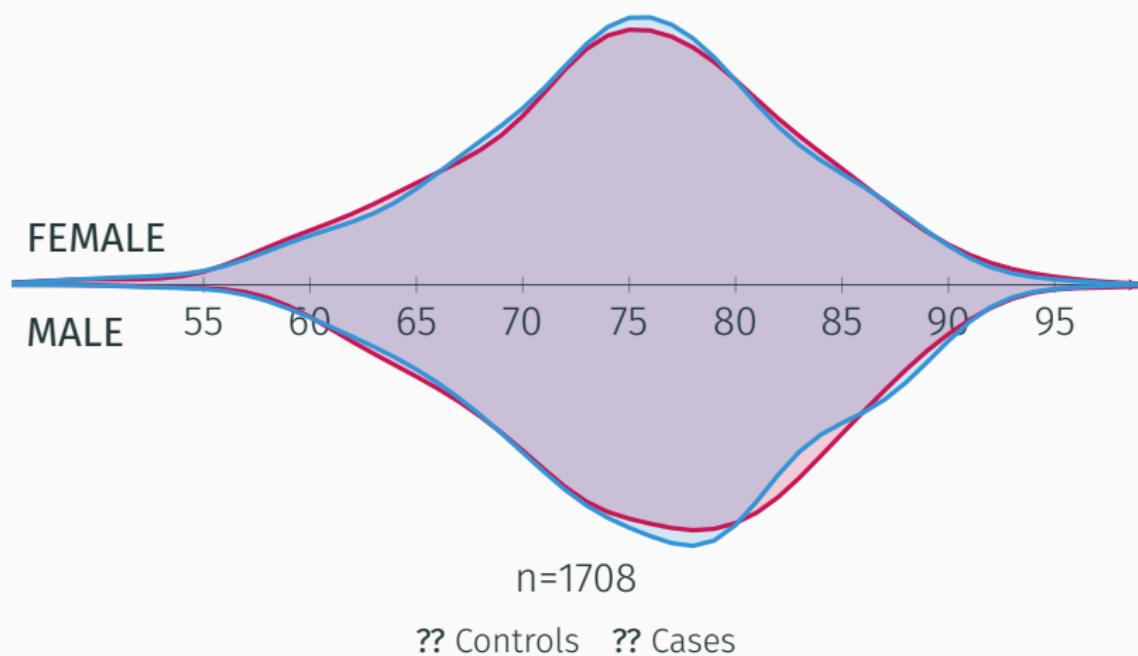


Case-control predictions

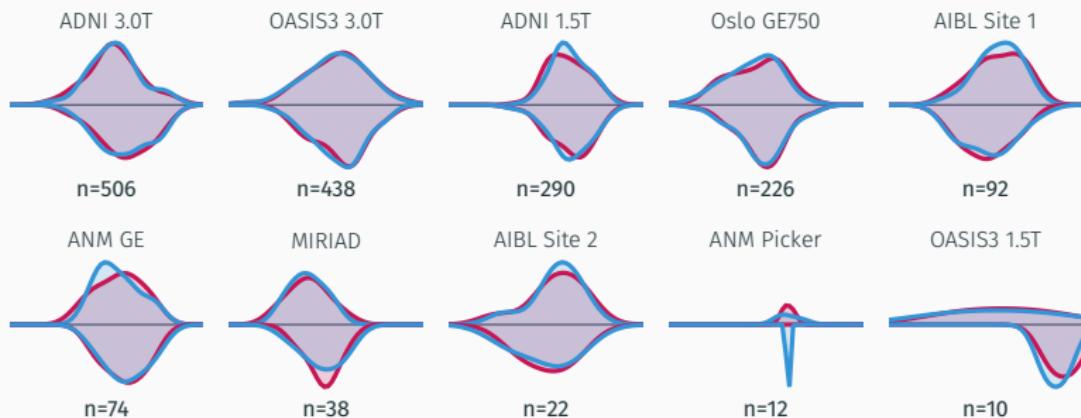
1. Train binary classification CNNs to detect signs of dementia in structural MRIs



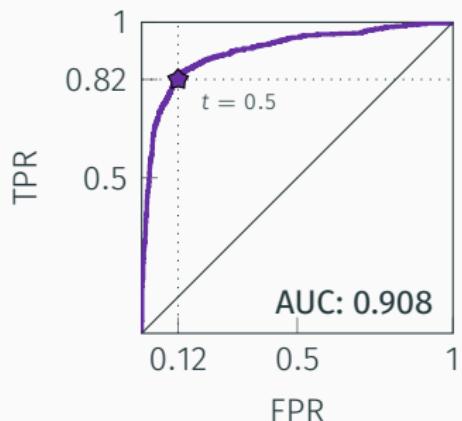
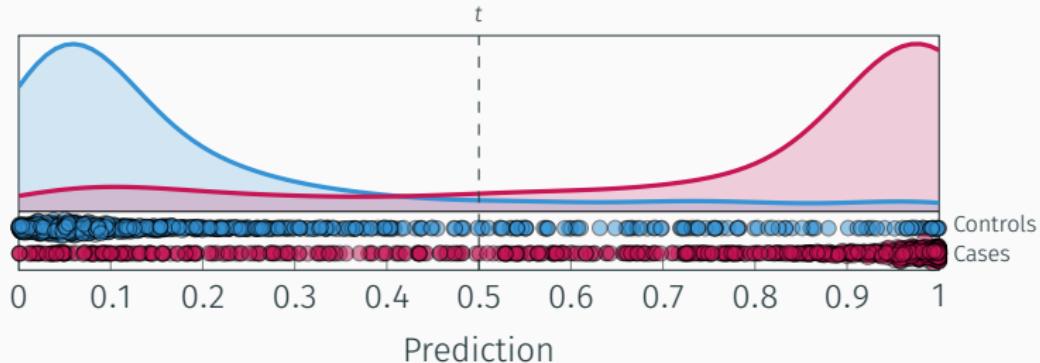
Case-control predictions



Case-control predictions



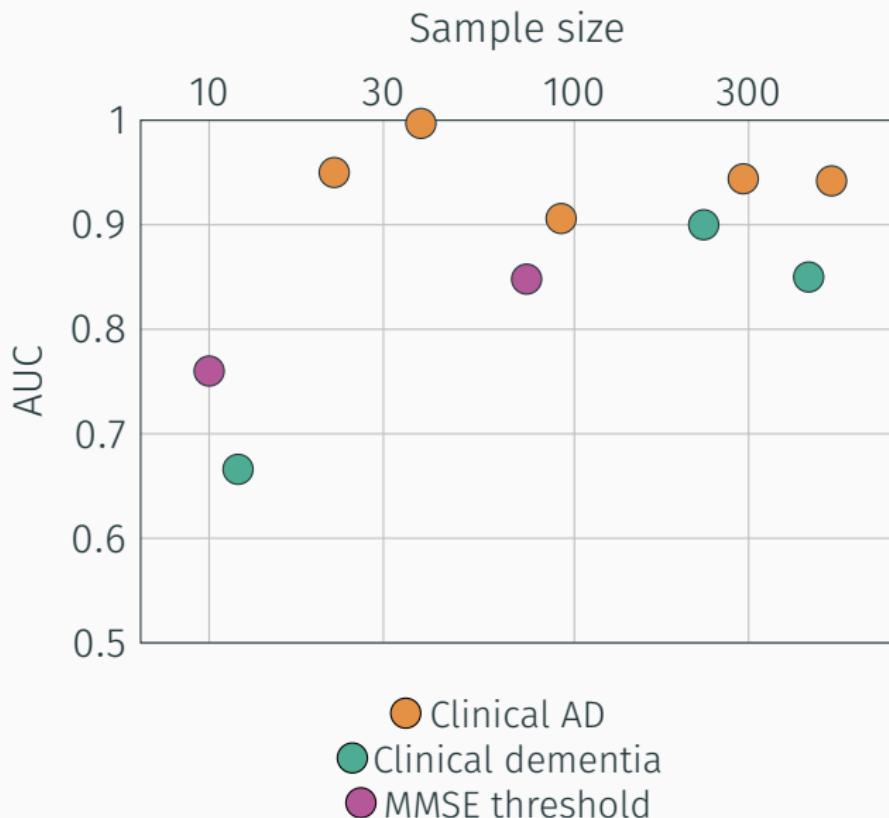
Case-control predictions



		Predicted	
		0	1
Observed	0	754	100
	1	157	697

Accuracy: 84.95%

Case-control predictions

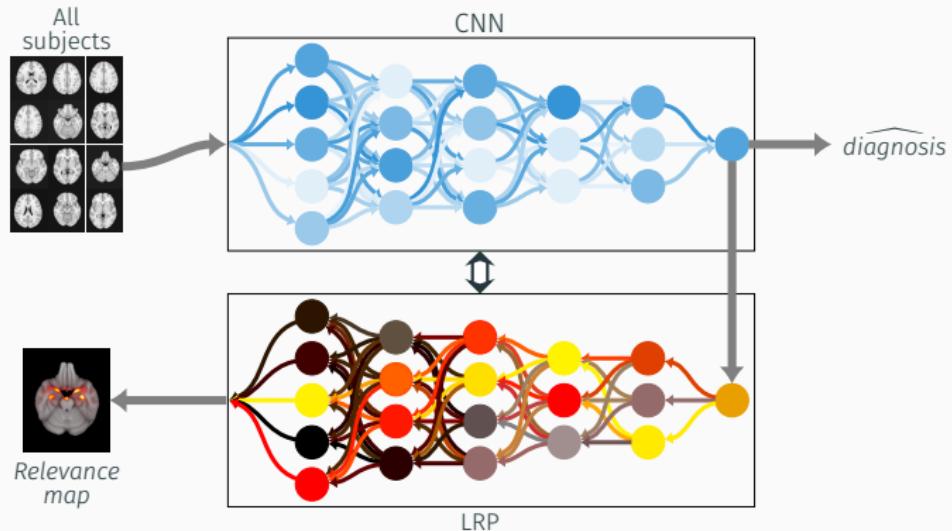


Case-control predictions

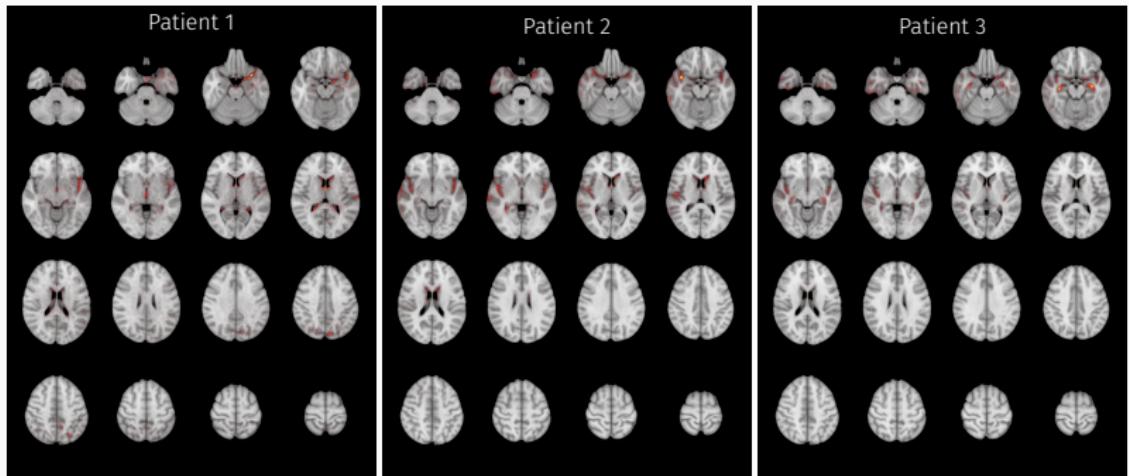
Sites	Size	AUC	Accuracy	Confusion Matrix	
ADNI 3.0T	506	0.942	90.11	237	16
				34	219
OASIS 3.0T	438	0.850	79.45	185	34
				56	163
ADNI 1.5T	290	0.944	87.93	125	20
				15	130
Oslo GE750	226	0.900	84.07	102	11
				25	88
AIBL Site 1	92	0.906	84.78	43	3
				11	35
ANM GE	74	0.848	72.97	26	11
				9	28
Miriad 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

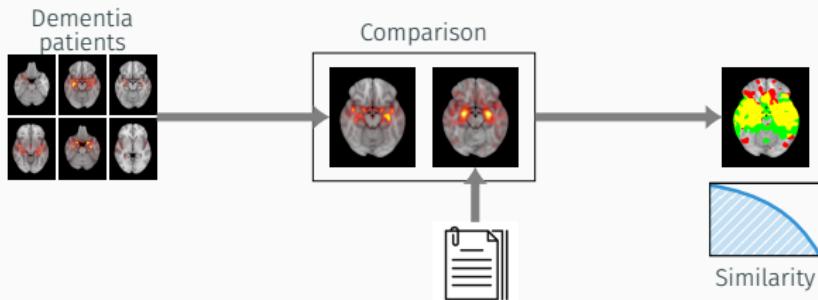


Generating relevance maps



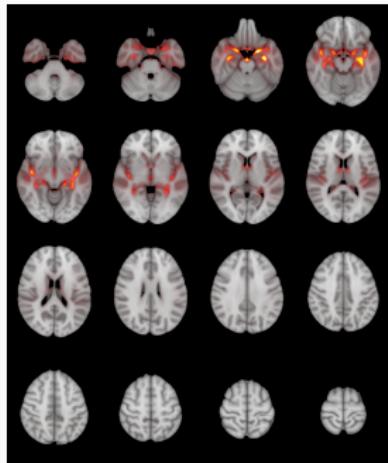
Validating relevance maps in dementia patients

3. Validate relevance maps for diagnosed patients against the literature



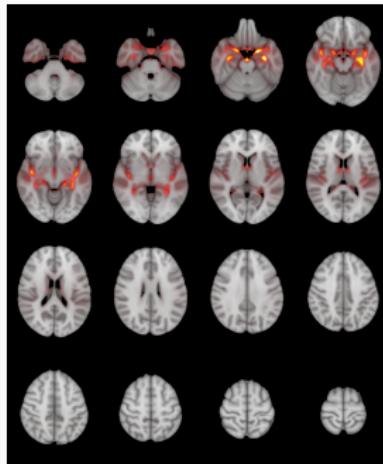
Validating relevance maps in dementia patients

Average dementia patient

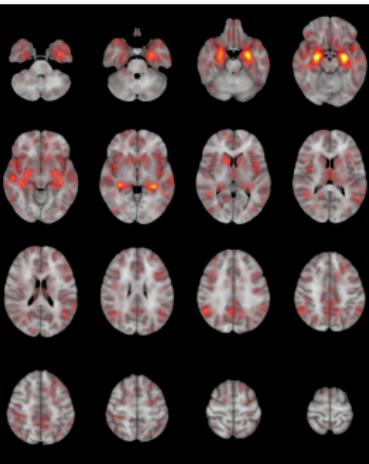


Validating relevance maps in dementia patients

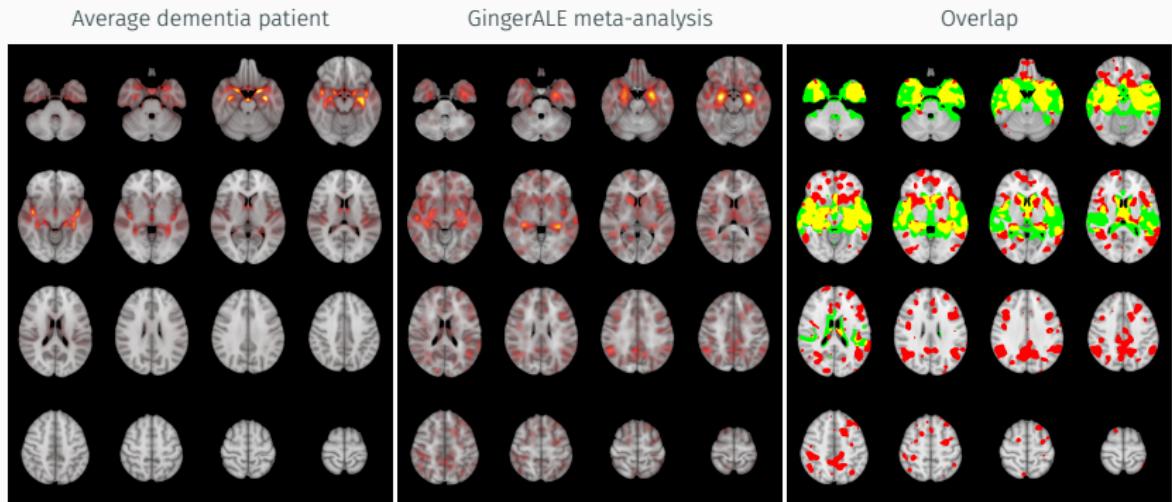
Average dementia patient



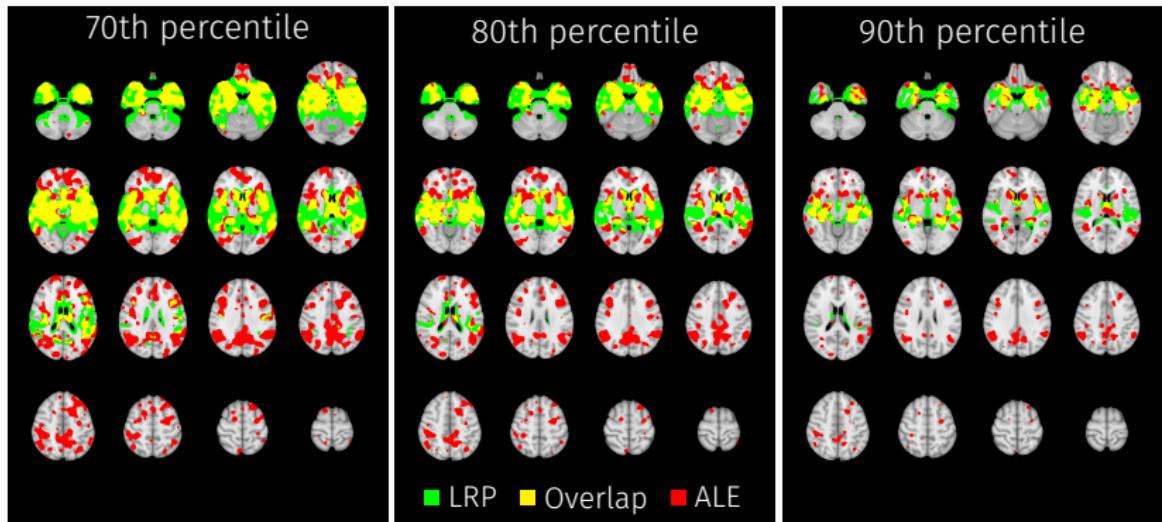
GingerALE meta-analysis



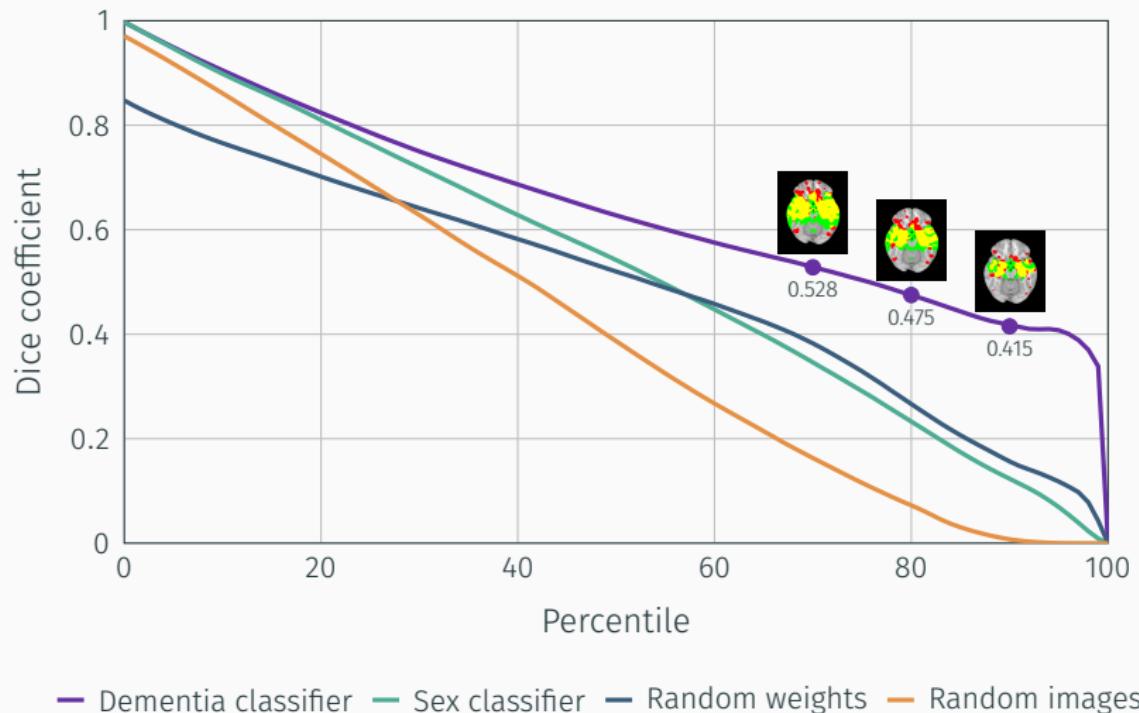
Validating relevance maps in dementia patients



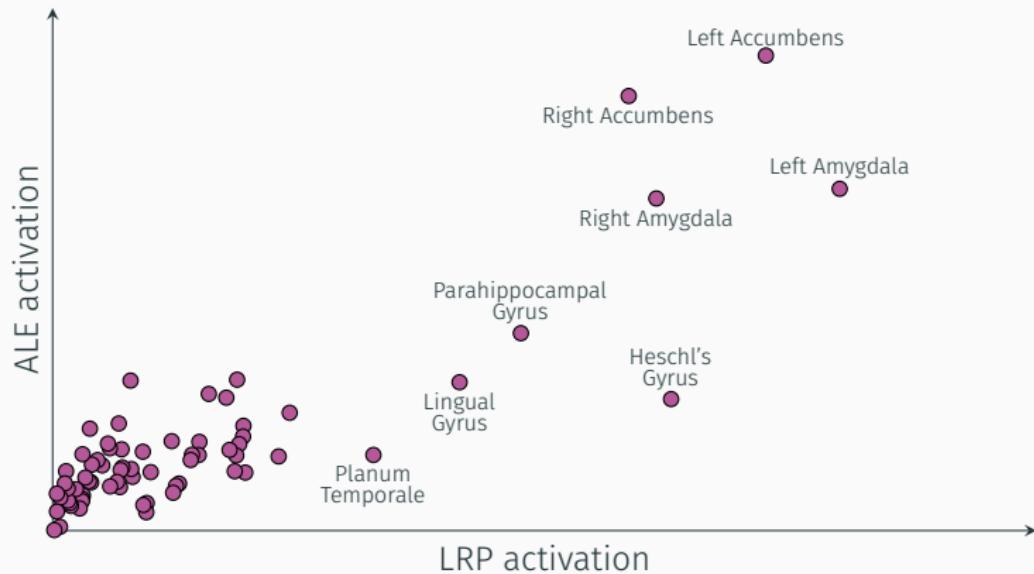
Validating relevance maps in dementia patients



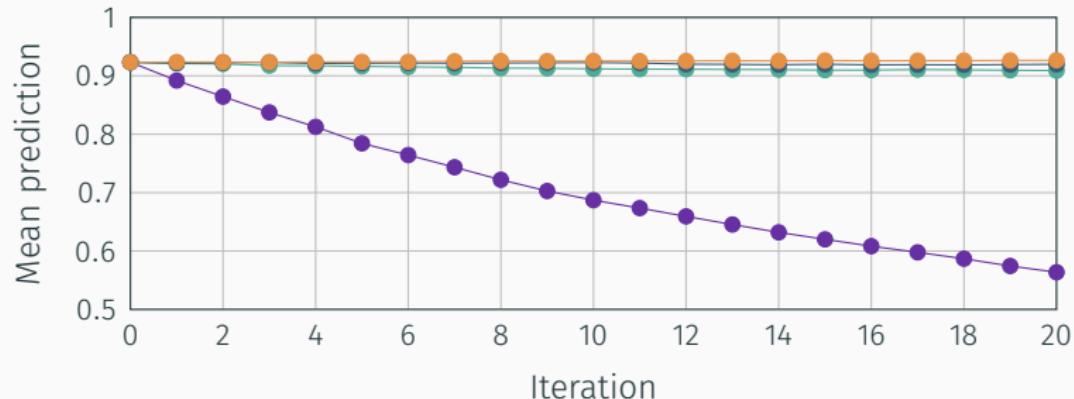
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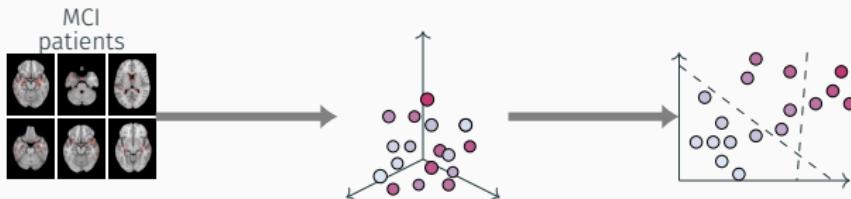
Validating relevance maps in dementia patients



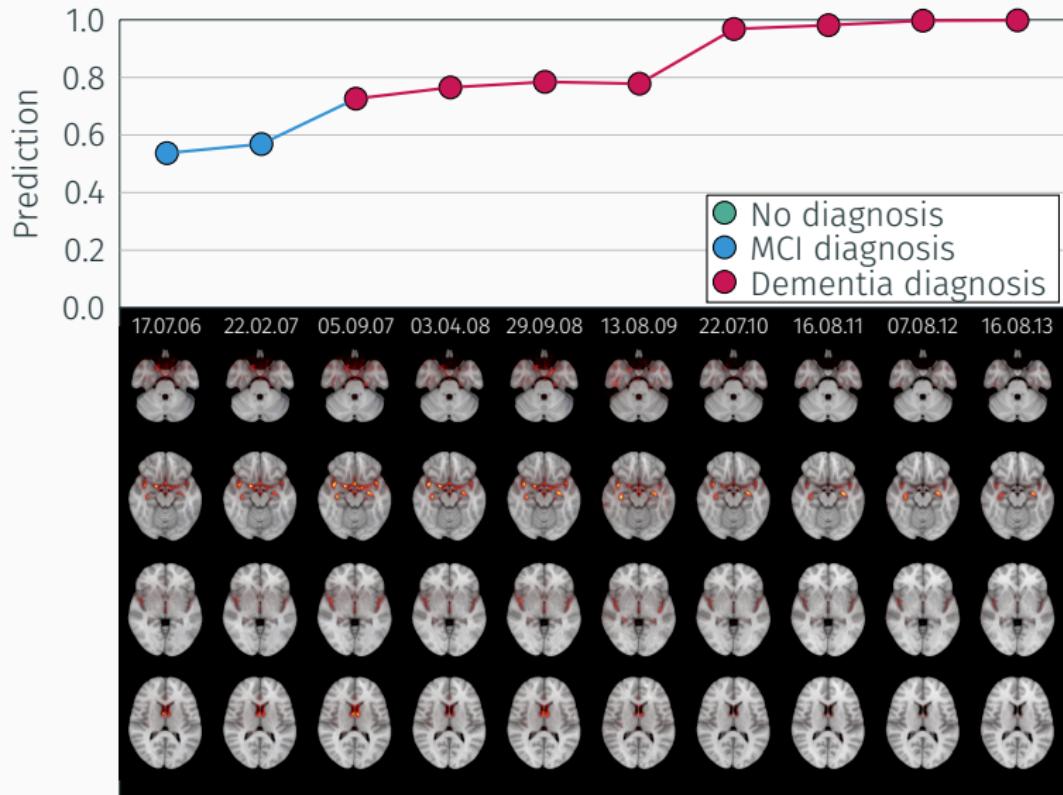
?? Dementia ?? Sex ?? Randomized weights ?? Randomized images

Exploring relevance maps in MCI patients

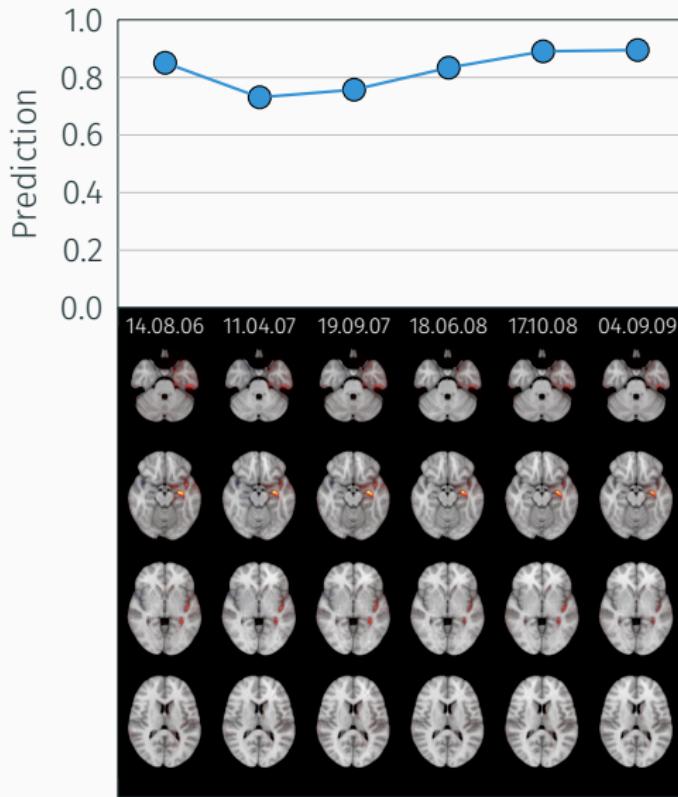
4. Stratify participants with MCI using predictions and relevance maps



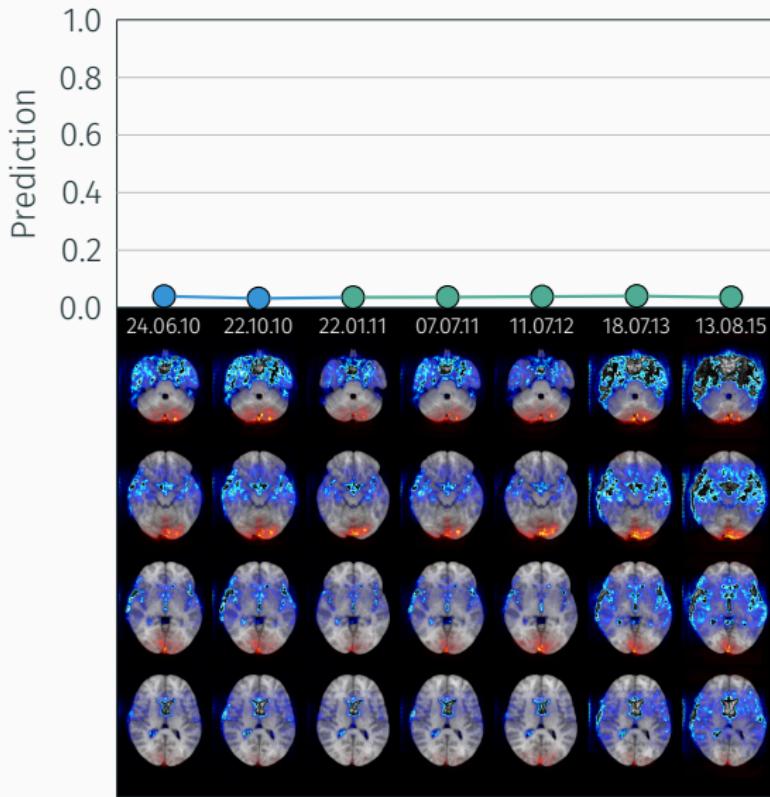
Exploring relevance maps in MCI patients



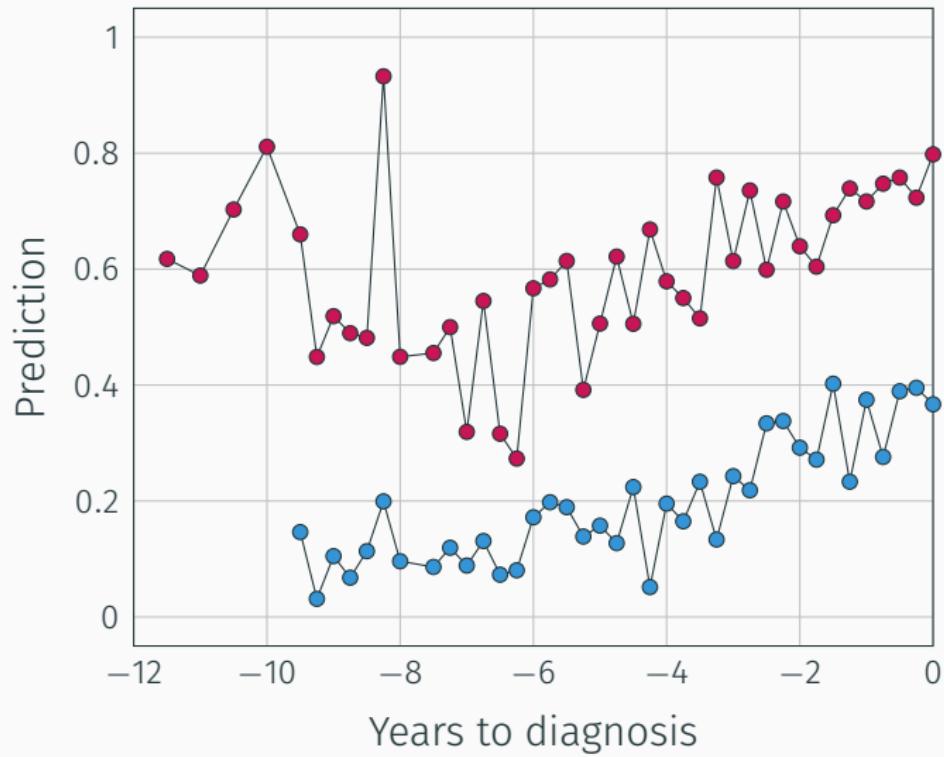
Exploring relevance maps in MCI patients



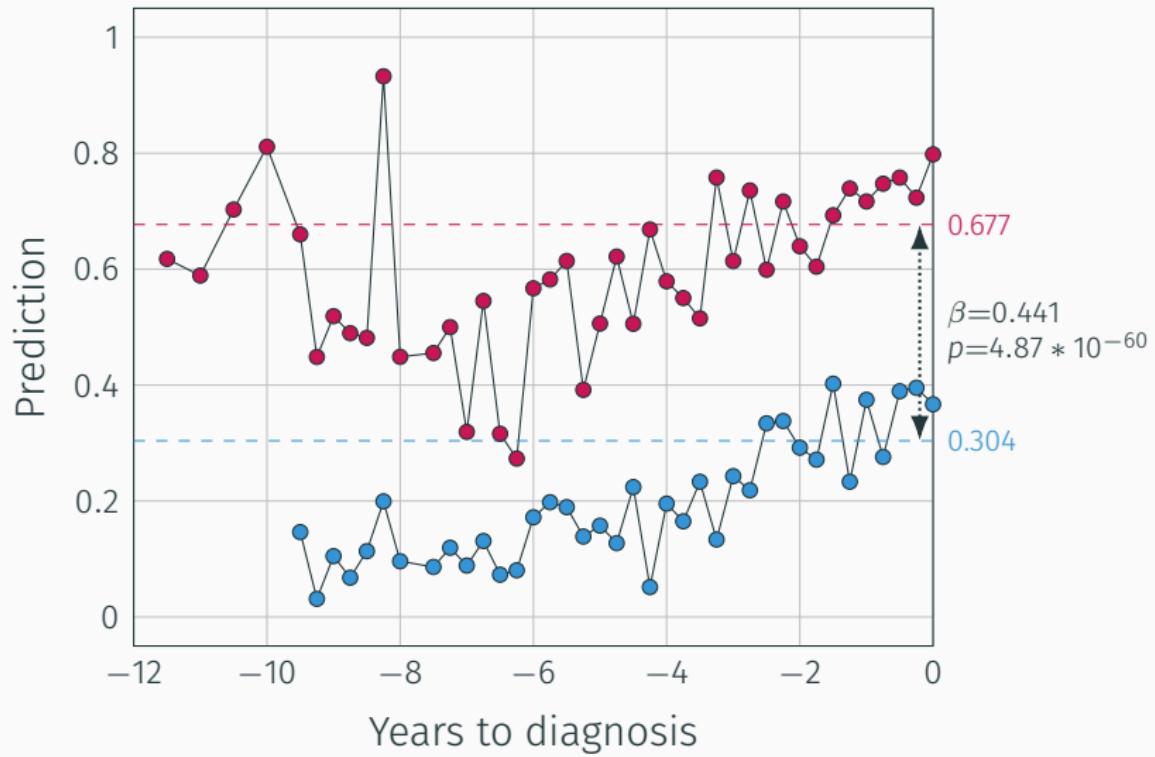
Exploring relevance maps in MCI patients



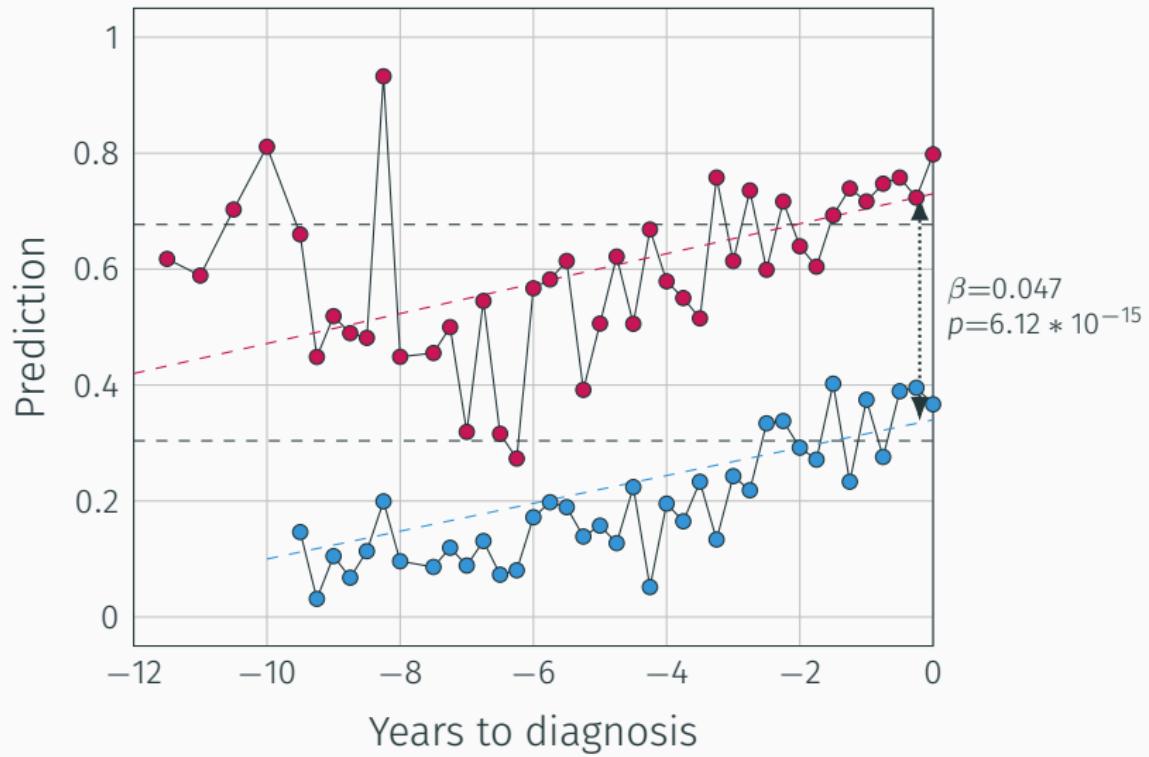
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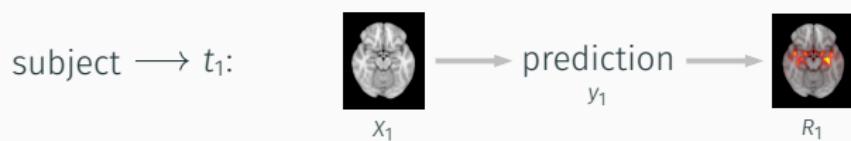
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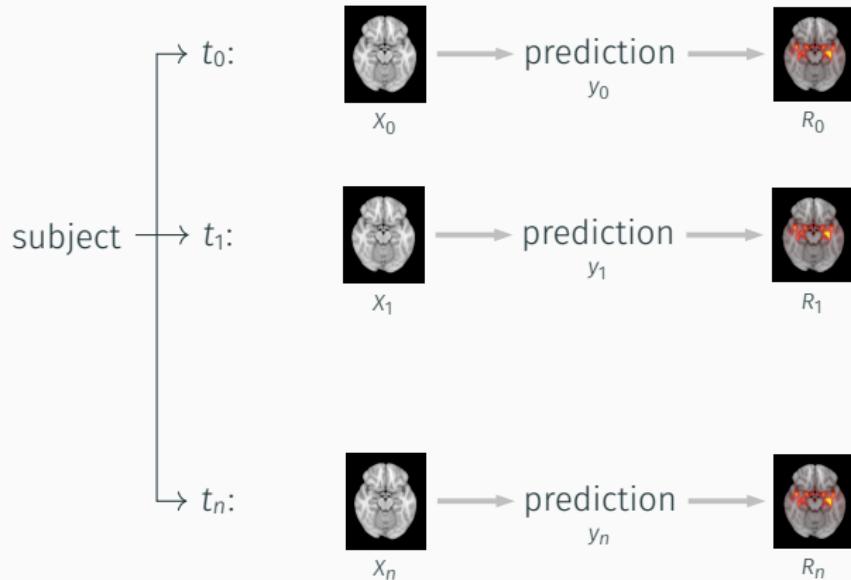
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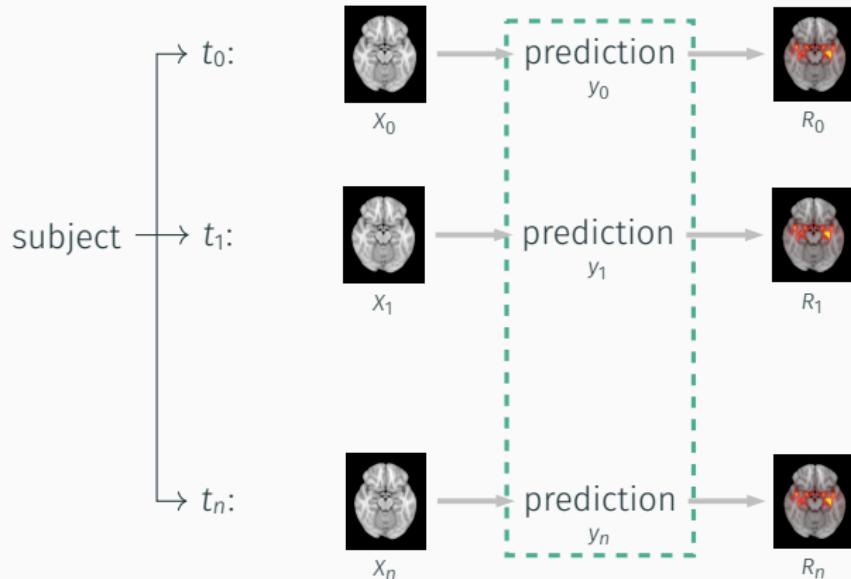
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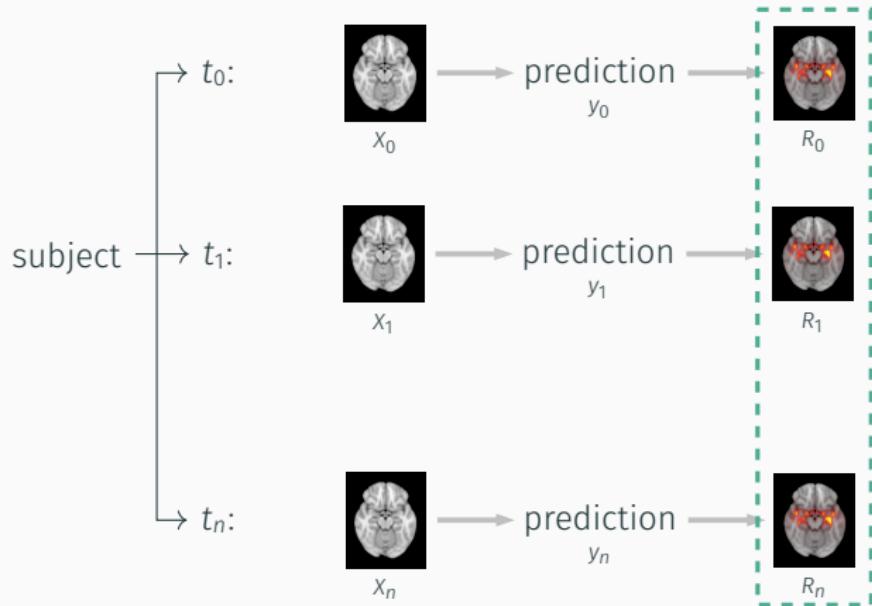
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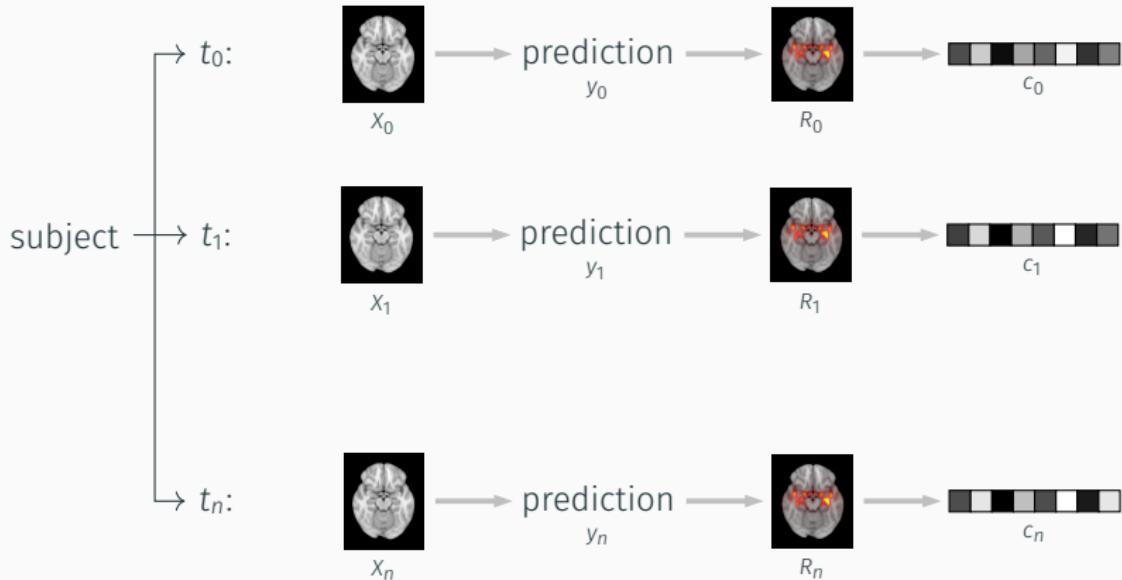
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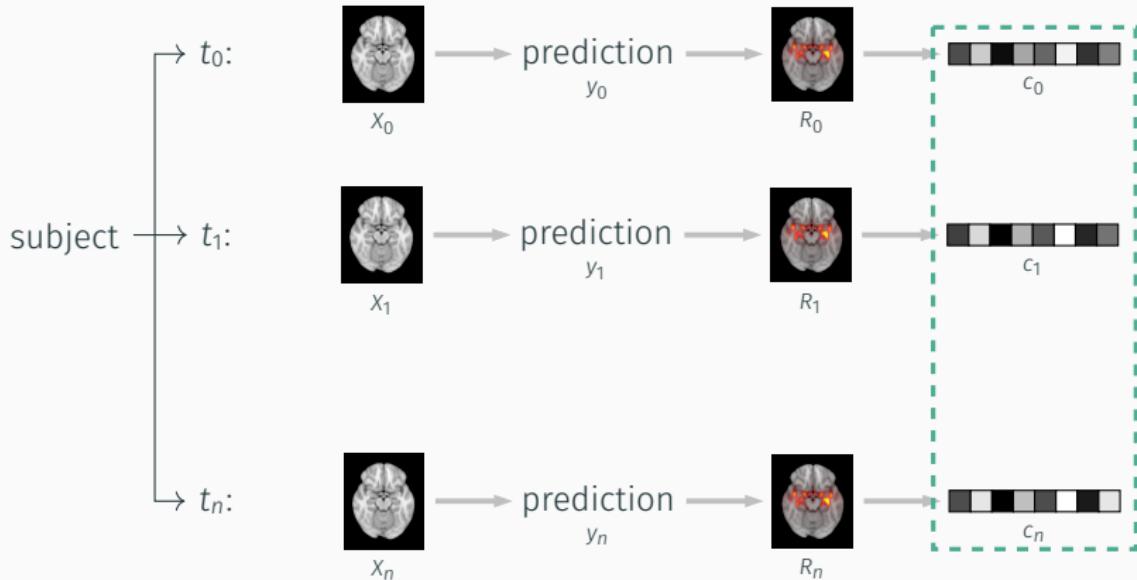
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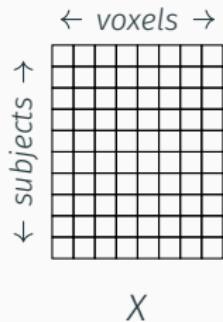
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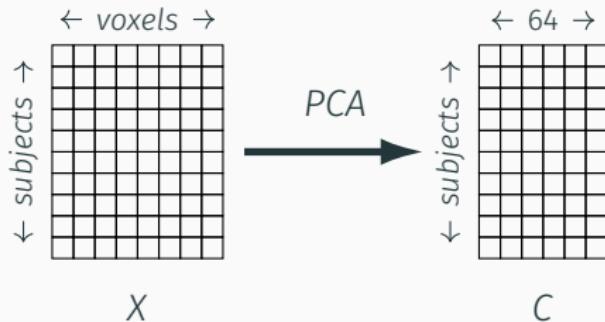
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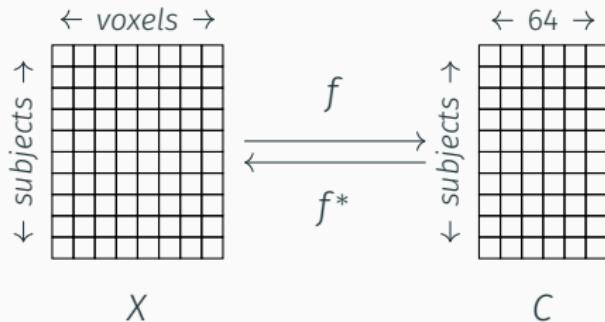
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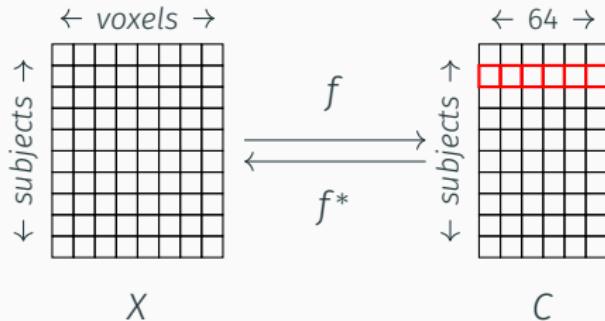
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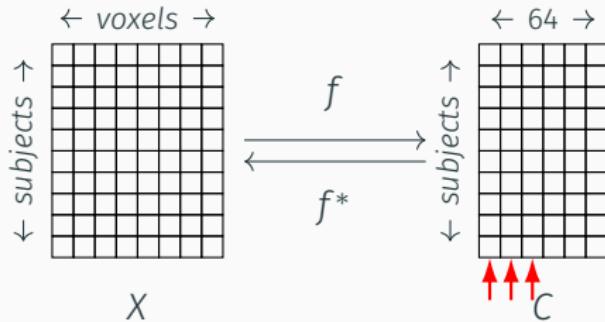
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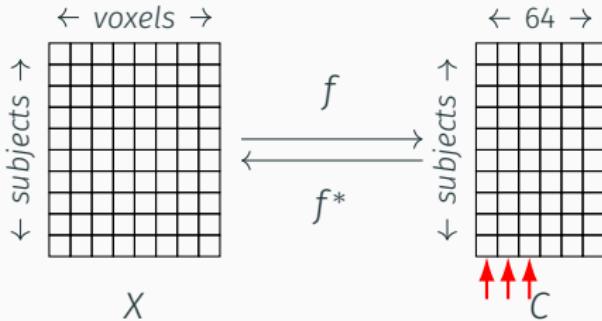
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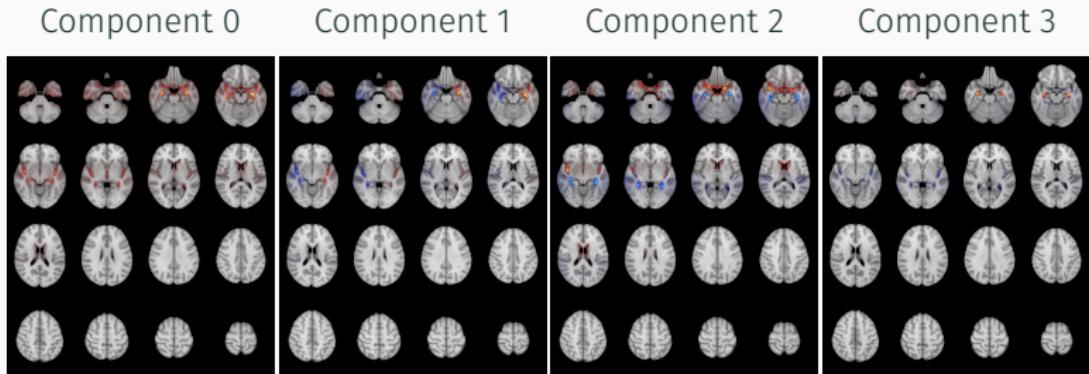


$$f^*([1, 0, 0, \dots, 0, 0, 0]) = ?$$

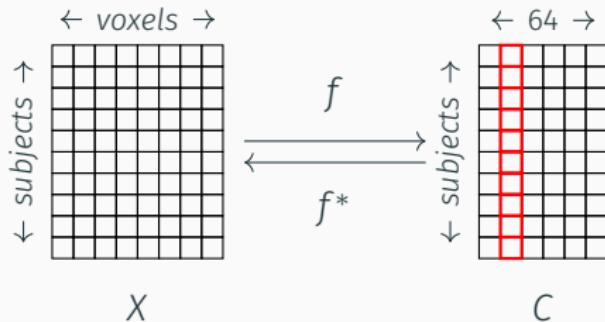
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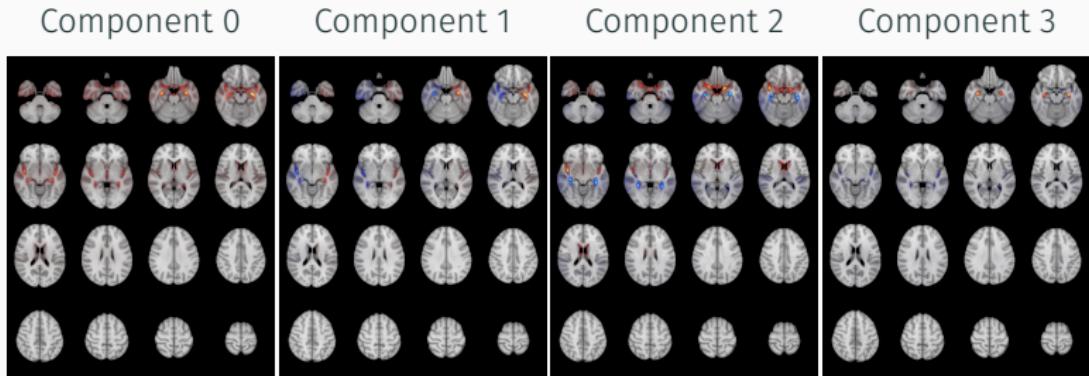
Exploring relevance maps in MCI patients



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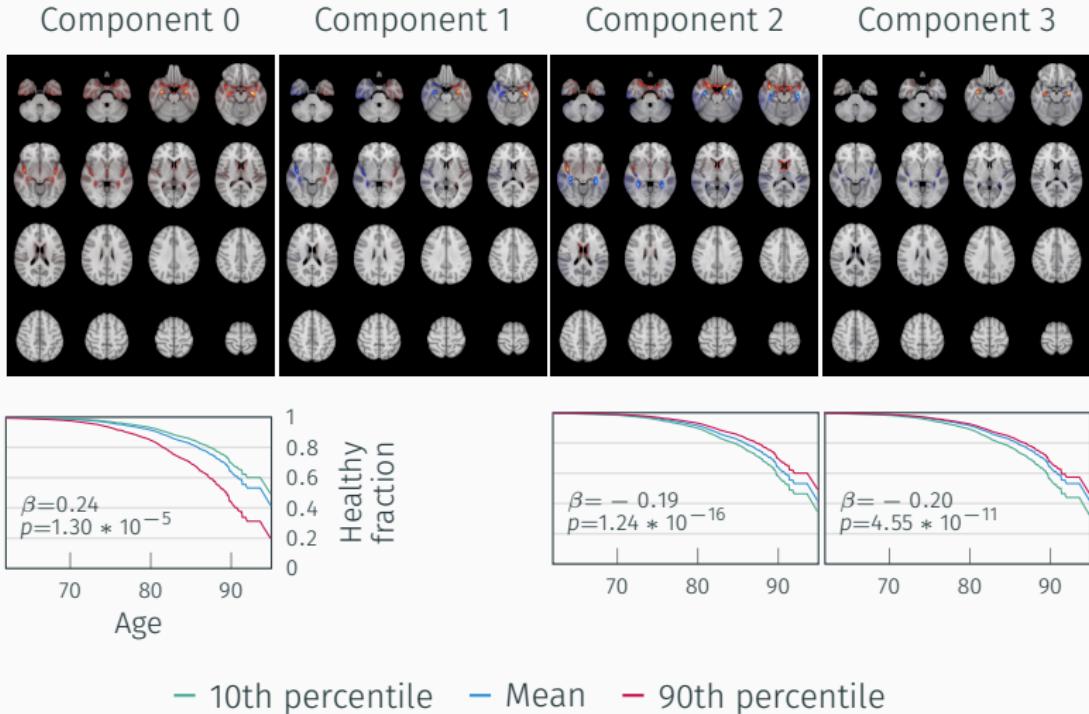


$$p=1.19 * 10^{-15}$$

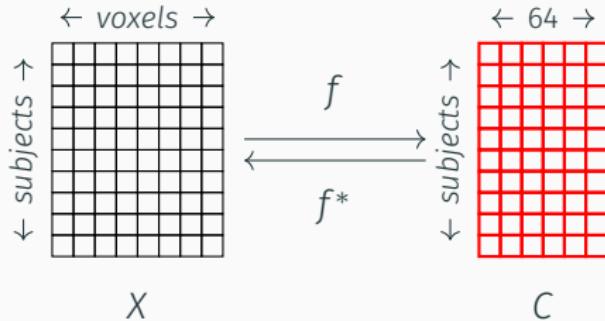
$$p=6.62 * 10^{-4}$$

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

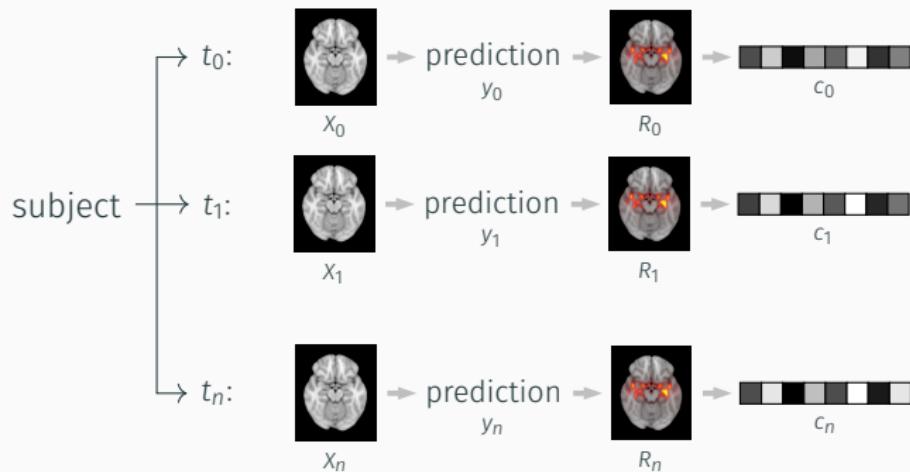
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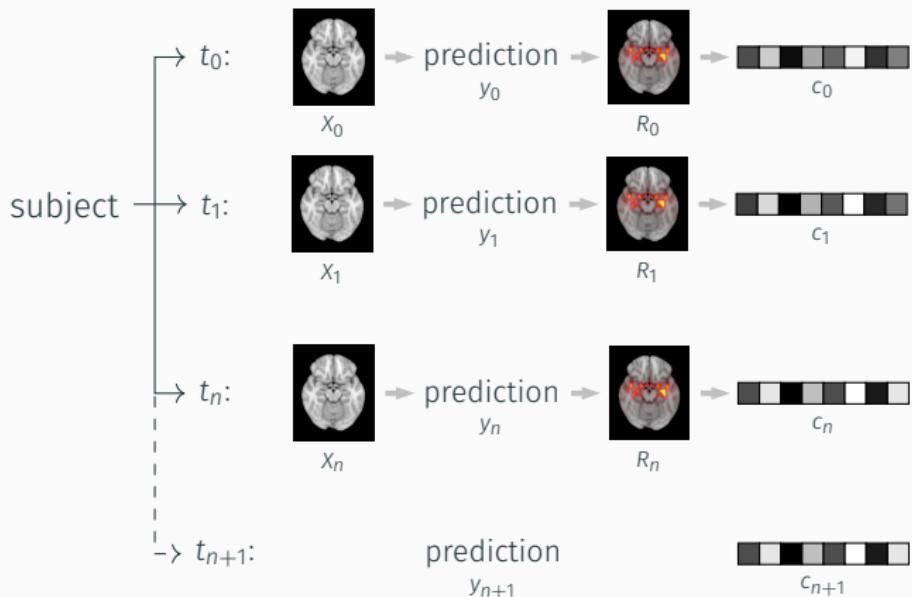
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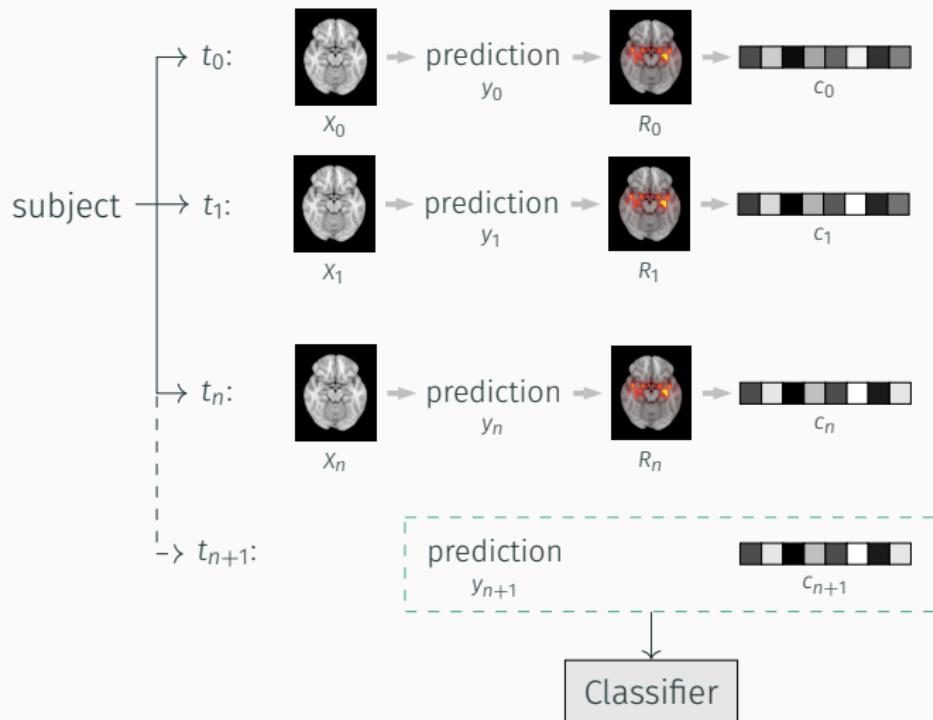
Exploring relevance maps in MCI patients



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Exploring relevance maps in MCI patients

Covariates	AUC	Accuracy	PPV	Sensitivity	Specificity
age + sex	0.521 ± 0.029	51.57 ± 3.56	0.61 ± 0.03	0.66 ± 0.03	0.37 ± 0.04
age + sex + \hat{y}_n	0.833 ± 0.077	75.23 ± 7.03	0.82 ± 0.10	0.72 ± 0.11	0.79 ± 0.09
age + sex + $\hat{y}_n + c_n$	0.855 ± 0.088	71.65 ± 7.51	0.90 ± 0.10	0.49 ± 0.12	0.93 ± 0.07
age + sex + $\hat{y}_{n+1}^* + c_{n+1}^*$	0.849 ± 0.074	76.97 ± 9.46	0.82 ± 0.10	0.78 ± 0.15	0.76 ± 0.08

Prediction of progression at t_{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."

Thank you!



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