

Artificial Intelligence in Healthcare

Identifying neuroimaging phenotypes with AI

Esten H. Leonardsen

07.02.25



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Outline

Plan for the day

1. Do we need new imaging phenotypes?
2. How can we identify new phenotypes with neural networks?
3. Use case: Explainable AI for dementia
4. Use case: Multitask pretraining
5. Use case: Explainable brain age predictions



How can we find new phenotypes with AI?

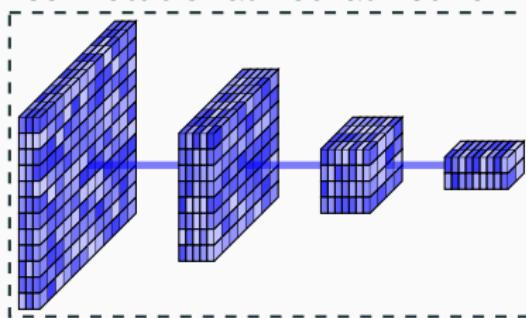


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What does neural networks do?



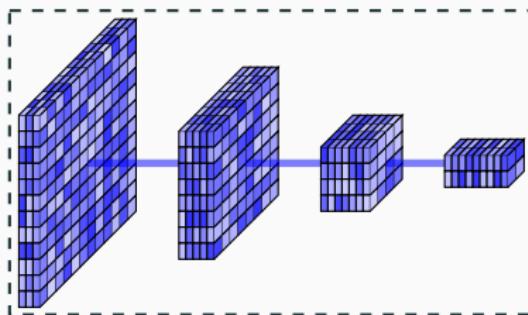
Convolutional neural network



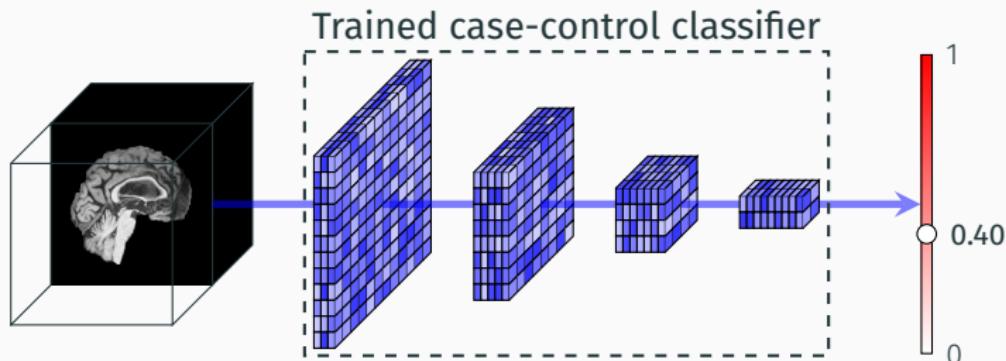
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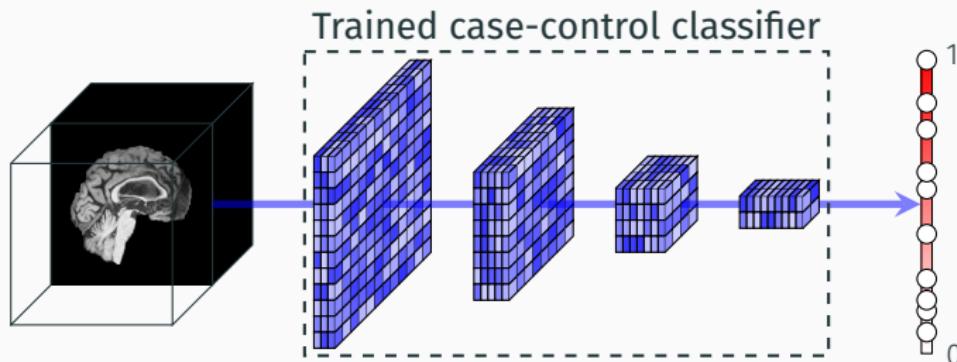
Trained case-control classifier



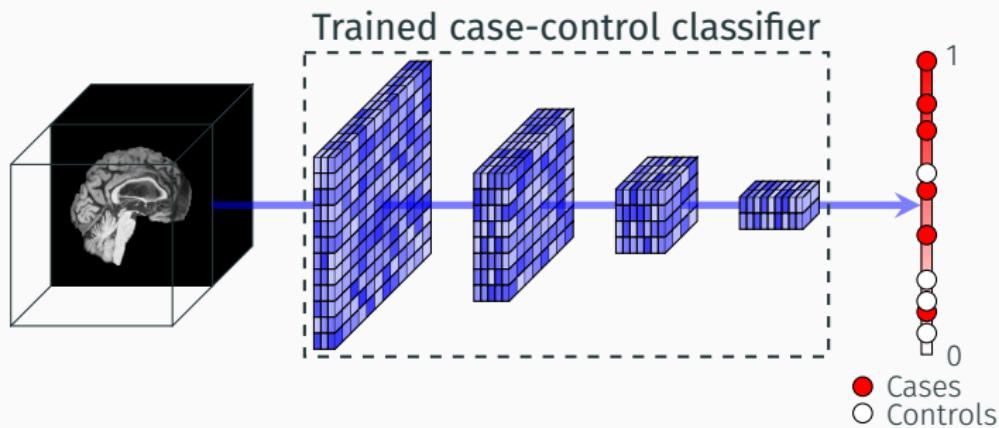
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What does neural networks do?



$$\hat{y} = \max(0, 0.45 * \max(0, 0.67 * \max(0, 0.12 * x_0 + 0.34 * x_1 + 0.56 * x_2 + 0.78 * x_3 + 0.91) + \\ 0.23 * \max(0, 0.11 * x_0 + 0.22 * x_1 + 0.33 * x_2 + 0.44 * x_3 + 0.55) + \\ 0.89 * \max(0, 0.66 * x_0 + 0.77 * x_1 + 0.88 * x_2 + 0.99 * x_3 + 0.10) + \\ 0.21) + \\ 0.54 * \max(0, 0.76 * \max(0, 0.12 * x_0 + 0.34 * x_1 + 0.56 * x_2 + 0.78 * x_3 + 0.91) + \\ 0.65 * \max(0, 0.11 * x_0 + 0.22 * x_1 + 0.33 * x_2 + 0.44 * x_3 + 0.55) + \\ 0.43 * \max(0, 0.66 * x_0 + 0.77 * x_1 + 0.88 * x_2 + 0.99 * x_3 + 0.10) + \\ 0.32) + \\ 0.98 * \max(0, 0.87 * \max(0, 0.12 * x_0 + 0.34 * x_1 + 0.56 * x_2 + 0.78 * x_3 + 0.91) + \\ 0.76 * \max(0, 0.11 * x_0 + 0.22 * x_1 + 0.33 * x_2 + 0.44 * x_3 + 0.55) + \\ 0.65 * \max(0, 0.66 * x_0 + 0.77 * x_1 + 0.88 * x_2 + 0.99 * x_3 + 0.10) + \\ 0.54) + \\ 0.31 * \max(0, 0.21 * \max(0, 0.12 * x_0 + 0.34 * x_1 + 0.56 * x_2 + 0.78 * x_3 + 0.91) + \\ 0.32 * \max(0, 0.11 * x_0 + 0.22 * x_1 + 0.33 * x_2 + 0.44 * x_3 + 0.55) + \\ 0.43 * \max(0, 0.66 * x_0 + 0.77 * x_1 + 0.88 * x_2 + 0.99 * x_3 + 0.10) + \\ 0.65) + \\ 0.06 * \max(0, 0.27 * \max(0, 0.12 * x_0 + 0.34 * x_1 + 0.56 * x_2 + 0.78 * x_3 + 0.91) + \\ 0.85 * \max(0, 0.11 * x_0 + 0.22 * x_1 + 0.33 * x_2 + 0.44 * x_3 + 0.55) + \\ 0.17 * \max(0, 0.66 * x_0 + 0.77 * x_1 + 0.88 * x_2 + 0.99 * x_3 + 0.10) + \\ 0.42) + \\ 0.76)$$



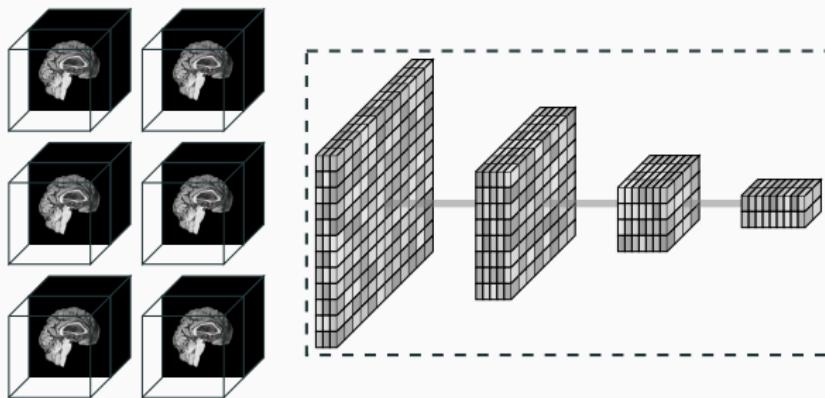
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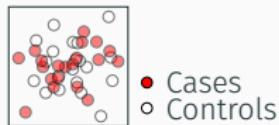
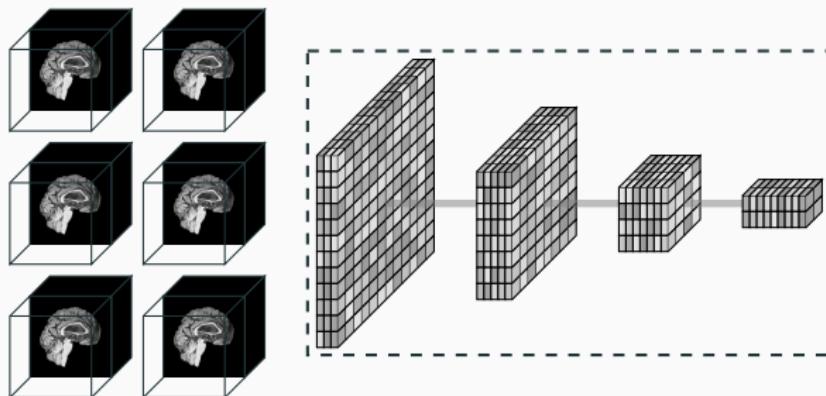

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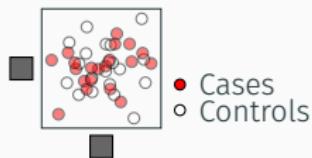
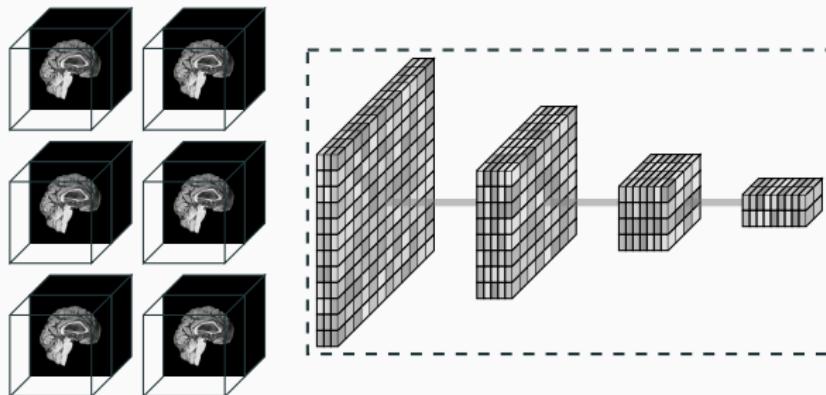

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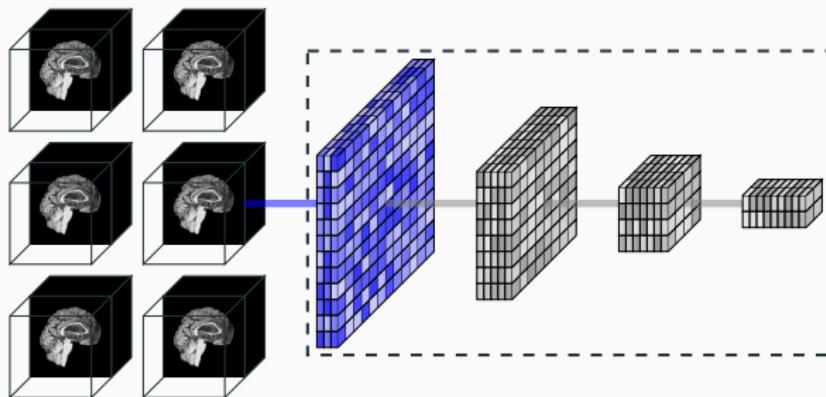
What does neural networks do?



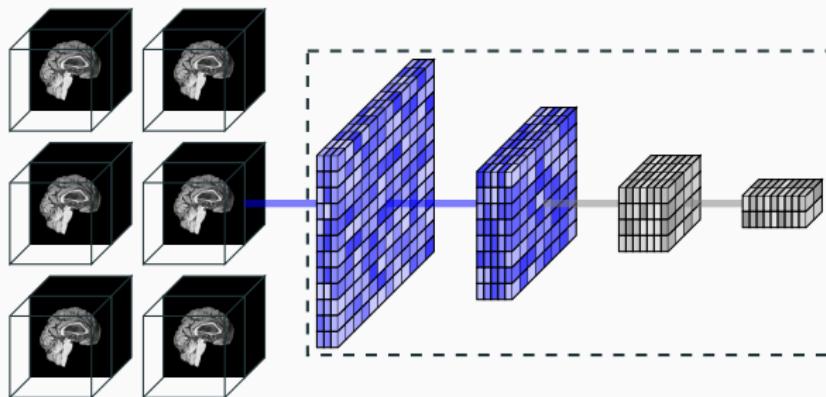
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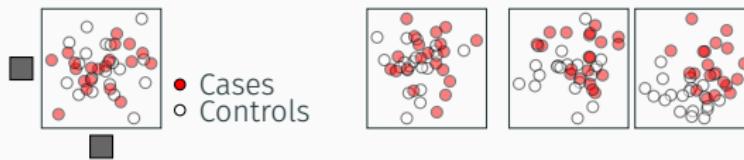
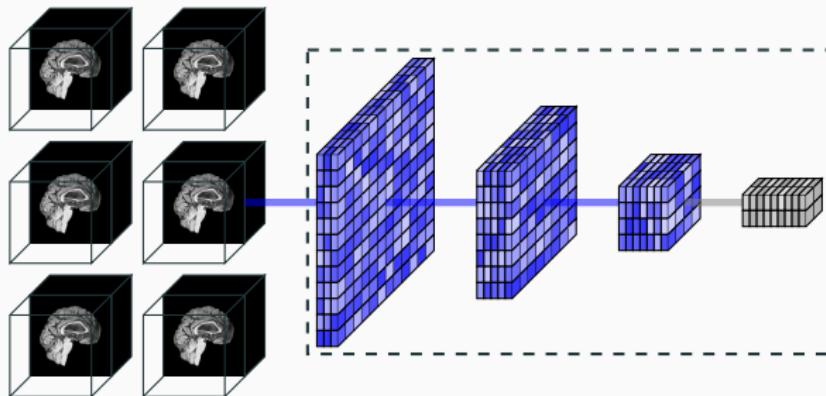
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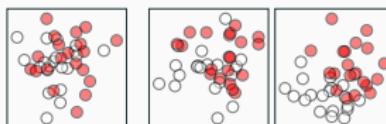
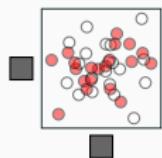
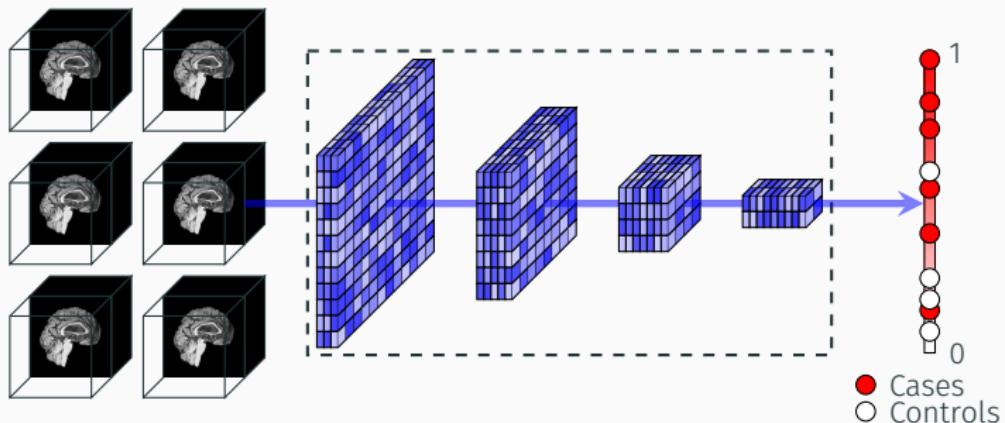
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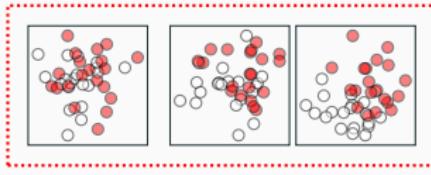
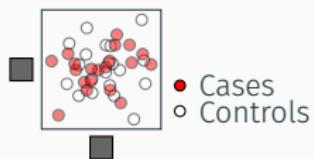
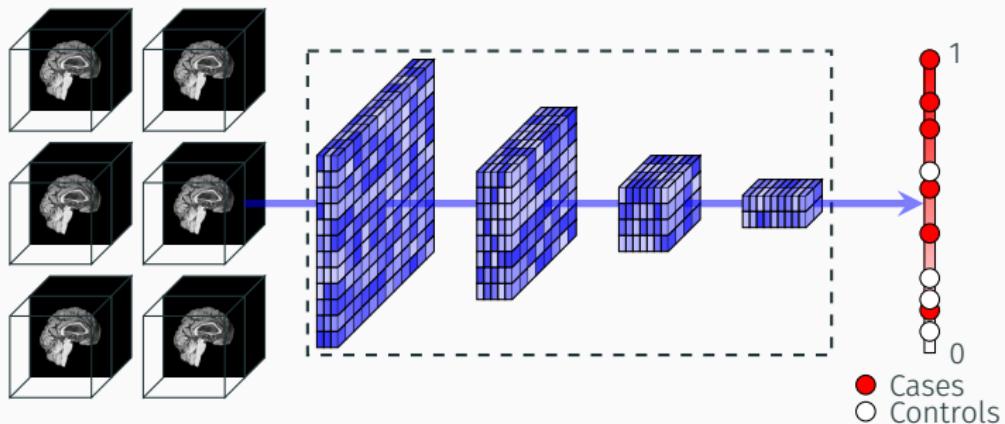
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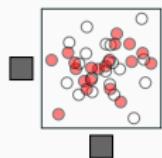
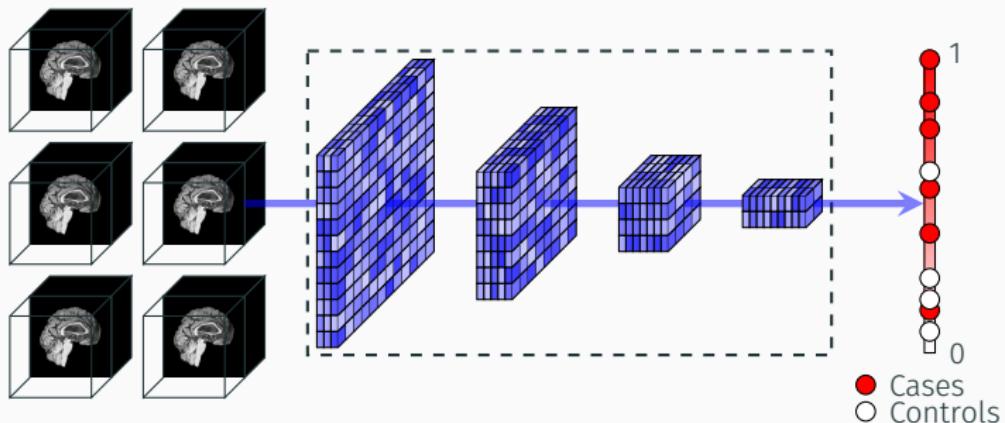
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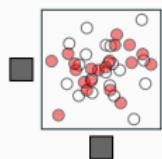
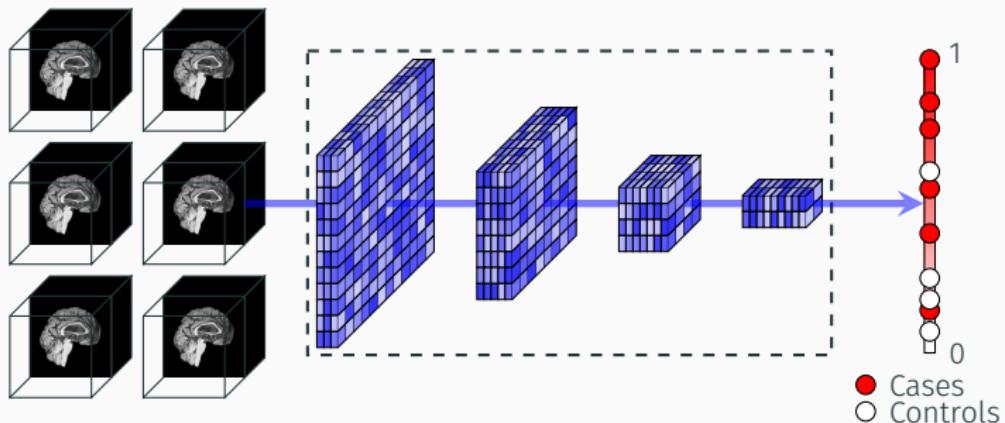
Feature spaces



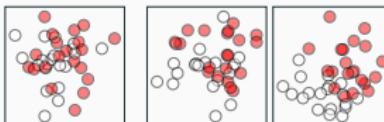
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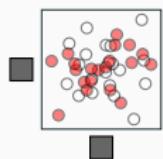
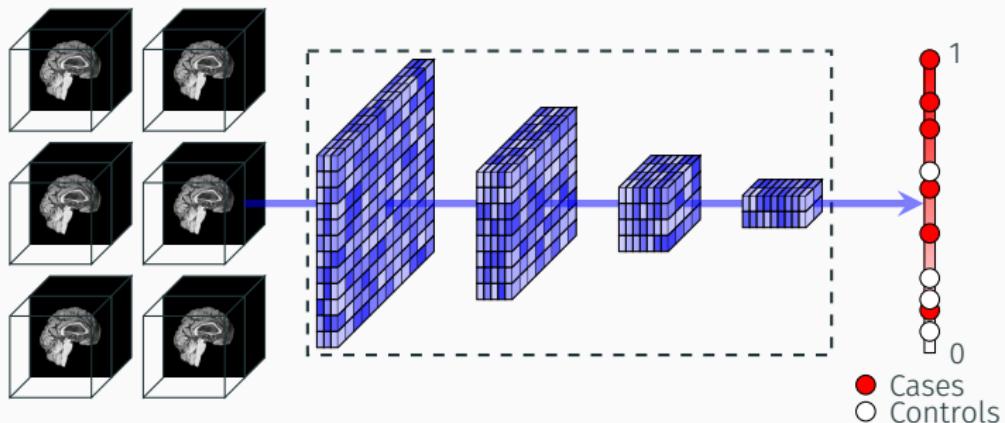
What does neural networks do?



● Cases
○ Controls



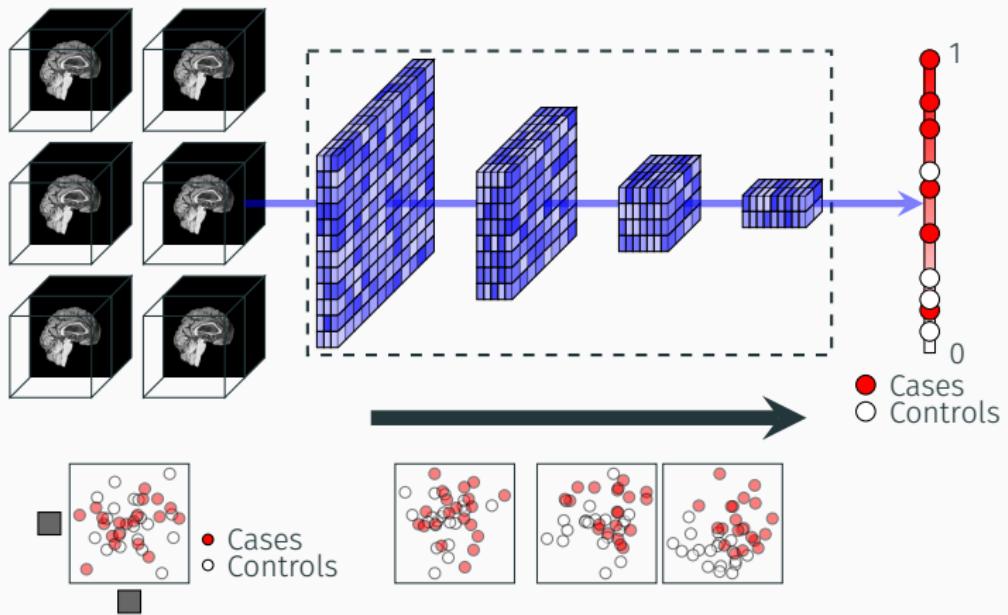
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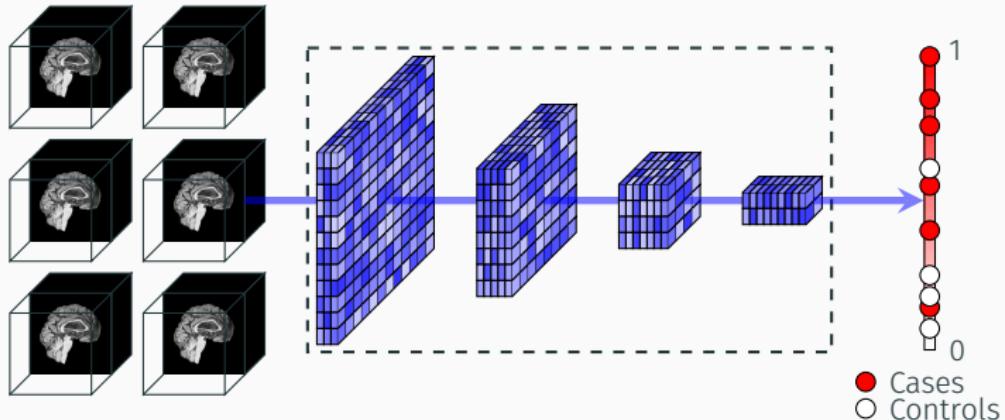
● Cases
○ Controls



What does neural networks do?



What does neural networks do?



How can we understand these learned features?



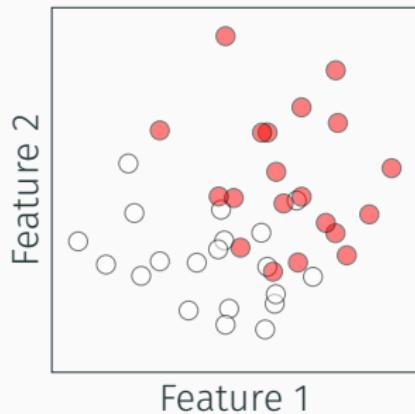
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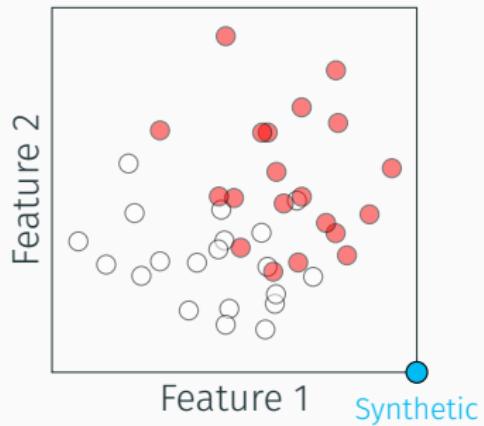
Explainable AI!



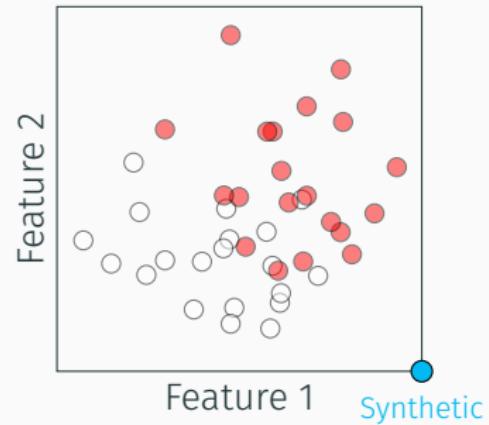
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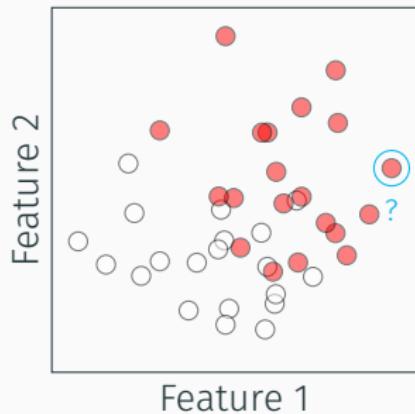
How can we understand these learned features?



Activation maximization

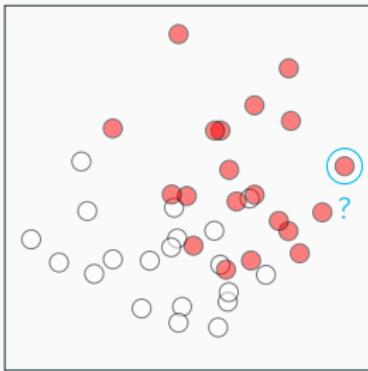


How can we understand these learned features?



How can we understand these learned features?

Feature 2

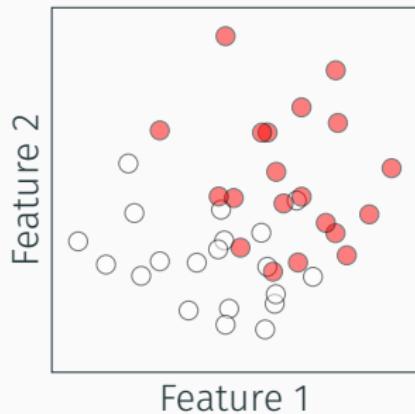


Feature 1

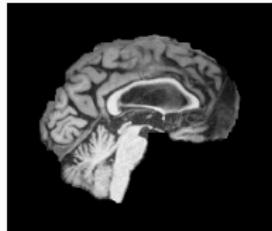
Saliency mapping



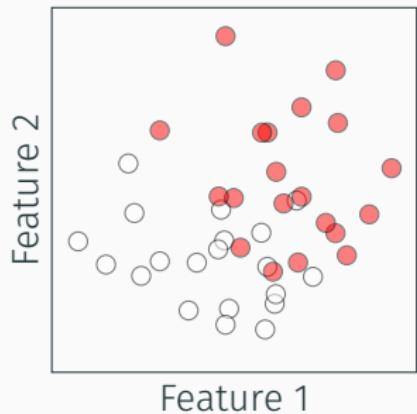
How can we understand these learned features?



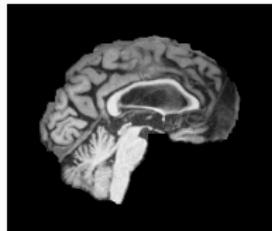
Feature 1



How can we understand these learned features?



Feature 1



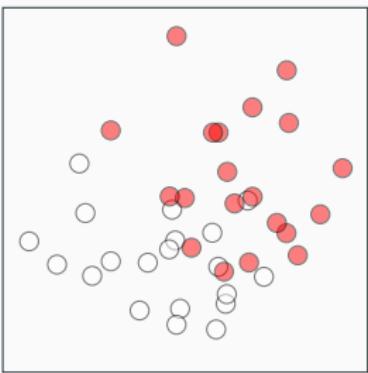
The patient shows
cortical atrophy, reduced
hippocampal volumes
and enlarged ventricles



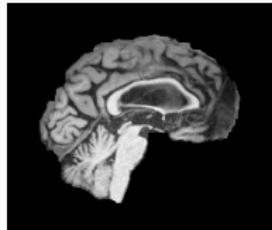
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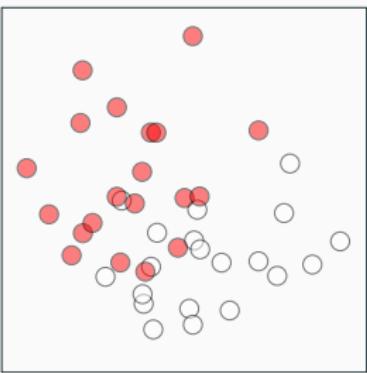
Feature 2



Feature 1



Feature 2



Feature 1

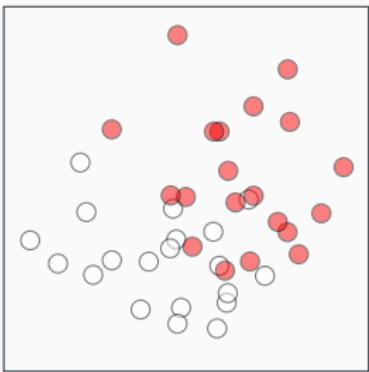
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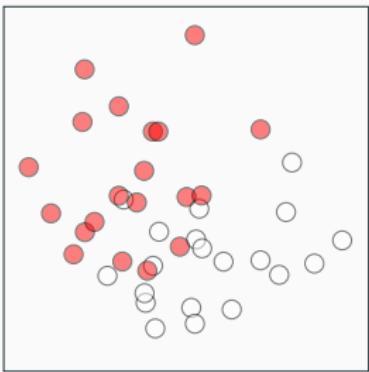
Feature 2



Feature 1



Feature 2



Feature 1

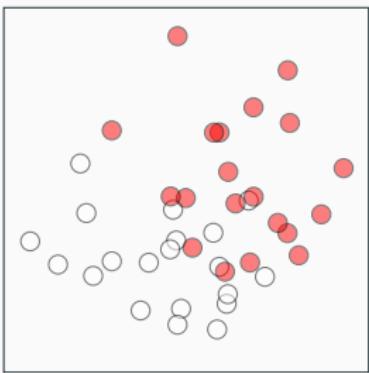
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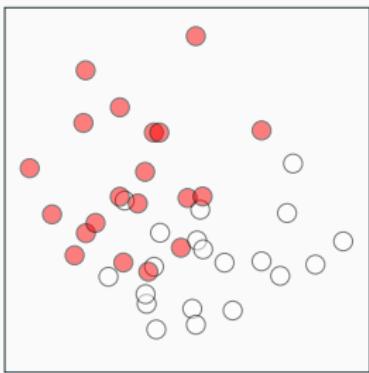
Feature 2



Feature 1



Feature 2



Feature 1

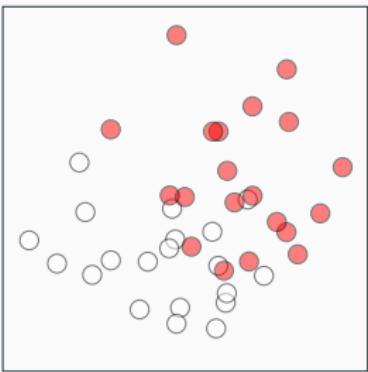
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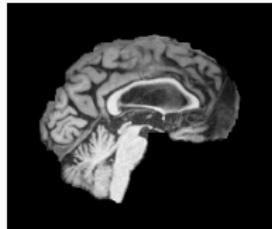
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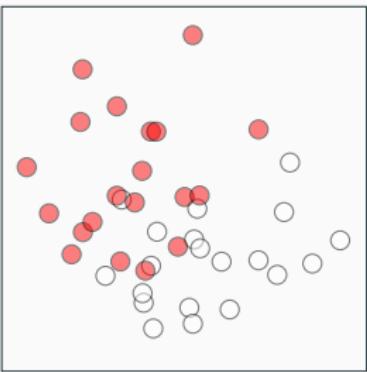
Feature 2



Feature 1



Feature 2



Feature 1

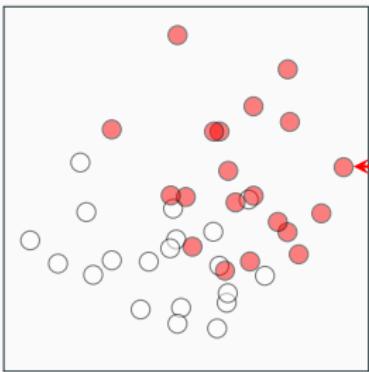
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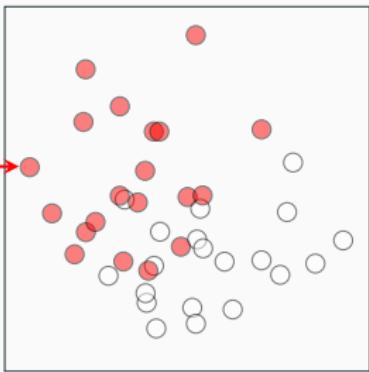


Feature 2



Feature 1

Feature 2



Feature 1



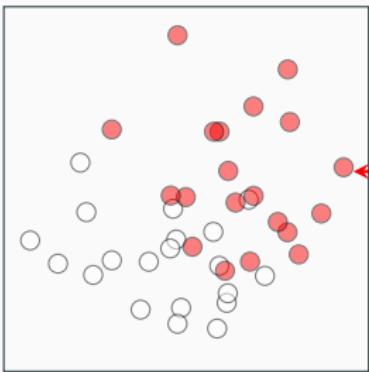
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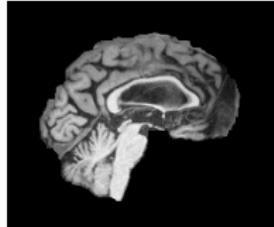
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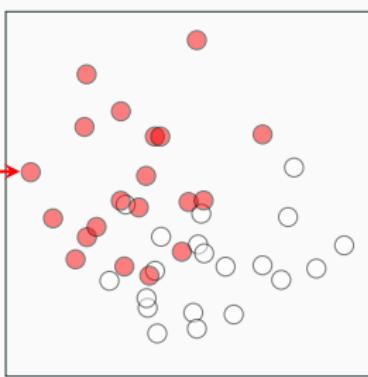
Feature 2



Cortical atrophy



Feature 2



Feature 1

The patient shows
cortical atrophy, reduced
hippocampal volumes
and enlarged ventricles



Use case: Dementia and XAI



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Dementia and explainable AI



FEMALE

MALE

55

60

65

70

75

80

85

90

95

n=1708

Controls
Patients

ADNI 3.0T

n=506

OASIS3 3.0T

n=438

ADNI 1.5T

n=290

Oslo GE750

n=226

AIBL Site 1

n=92

ANM GE

n=74

MIRIAD

n=38

AIBL Site 2

n=22

ANM Picker

n=12

OASIS3 1.5T

n=10



Dementia and explainable AI



CNN



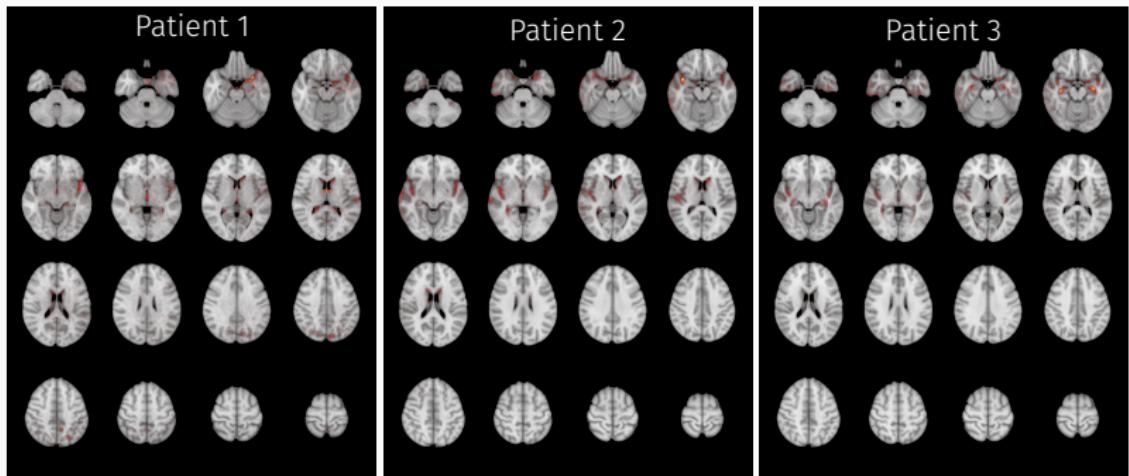
Dementia and explainable AI



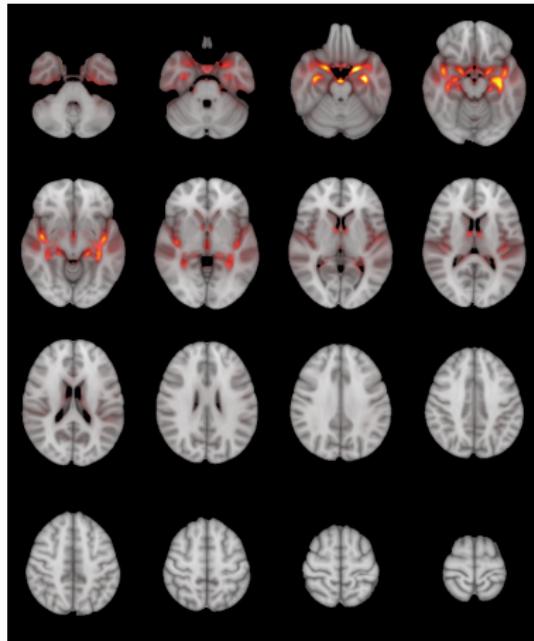
LRP



Dementia and explainable AI



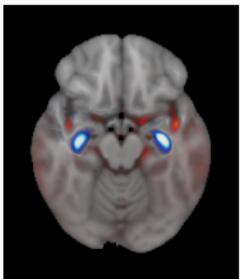
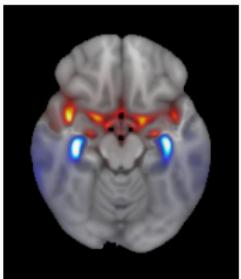
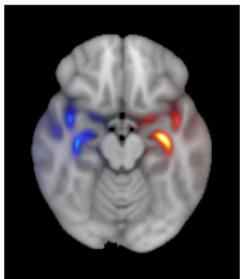
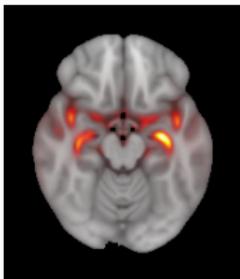
Dementia and explainable AI



Dementia and explainable AI



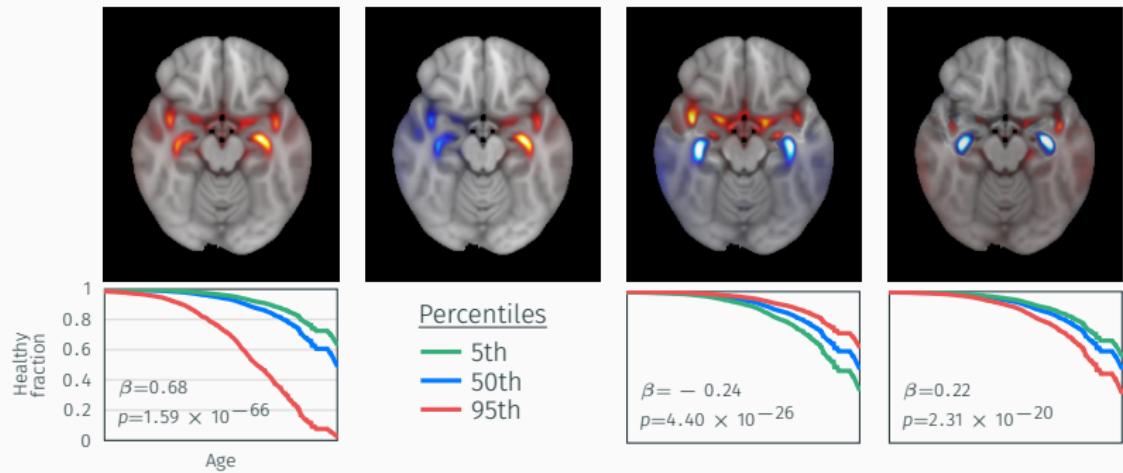
Component 0 Component 1 Component 2 Component 3



Dementia and explainable AI



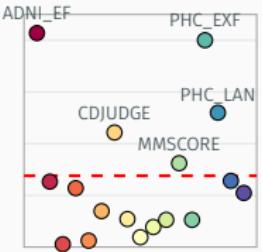
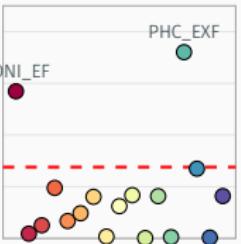
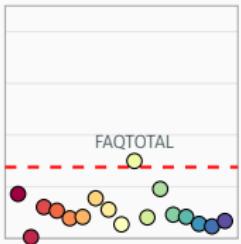
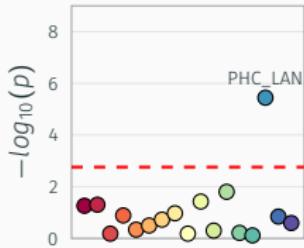
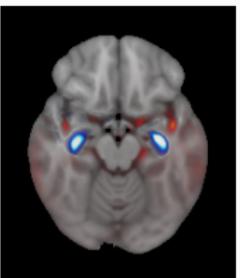
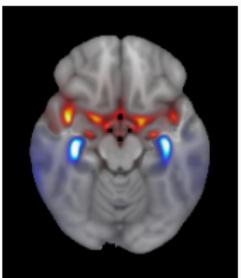
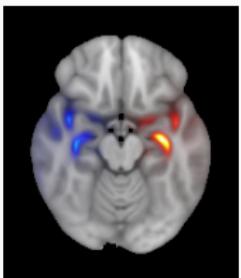
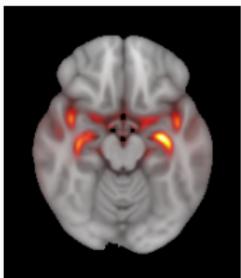
Component 0 Component 1 Component 2 Component 3



Dementia and explainable AI



Component 0 Component 1 Component 2 Component 3



Multitask pretraining

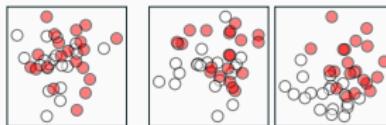
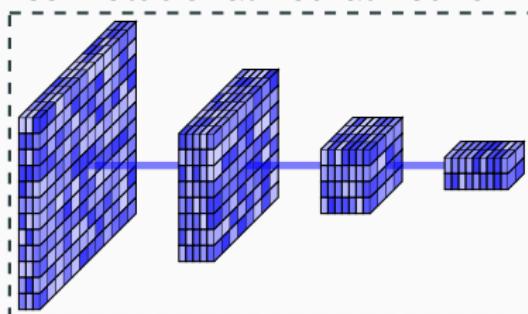


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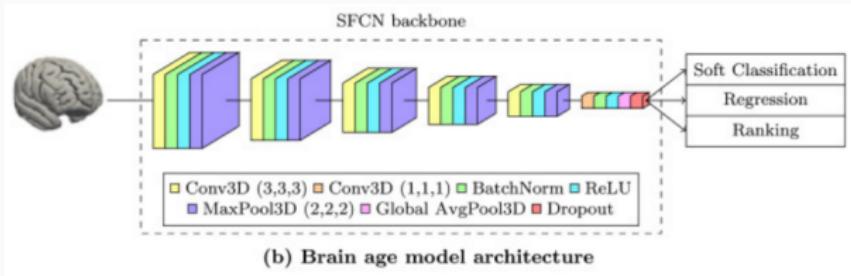
Multitask pretraining



Convolutional neural network



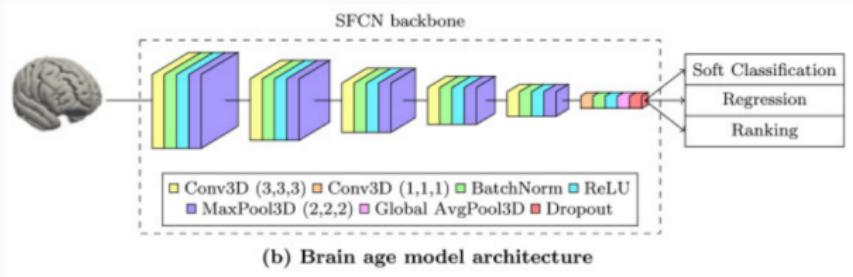
Multitask pretraining



Leonardsen, E. H., Peng, H., Kaufmann, T., Agartz, I., Andreassen, O. A., Celius, E. G., ... & Wang, Y. (2022). "Deep neural networks learn general and clinically relevant representations of the ageing brain". *NeuroImage*, 256, 119210.



Multitask pretraining



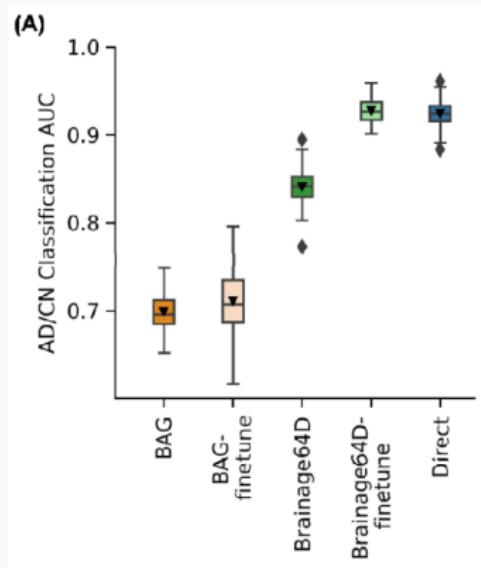
"Furthermore, we see this result as evidence that deep learning models trained to predict age in large multisite datasets constitute excellent starting points for transfer learning, which can subsequently be fine-tuned to a variety of tasks."

- Esten et al.

Leonardsen, E. H., Peng, H., Kaufmann, T., Agartz, I., Andreassen, O. A., Celius, E. G., ... & Wang, Y. (2022). "Deep neural networks learn general and clinically relevant representations of the ageing brain". *NeuroImage*, 256, 119210.



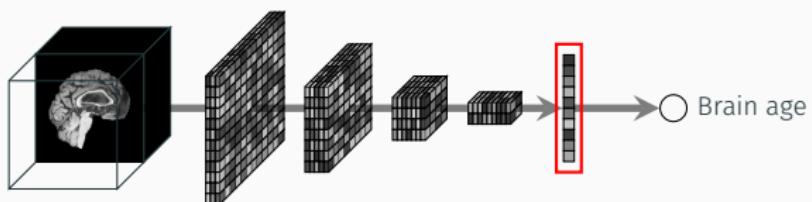
Multitask pretraining



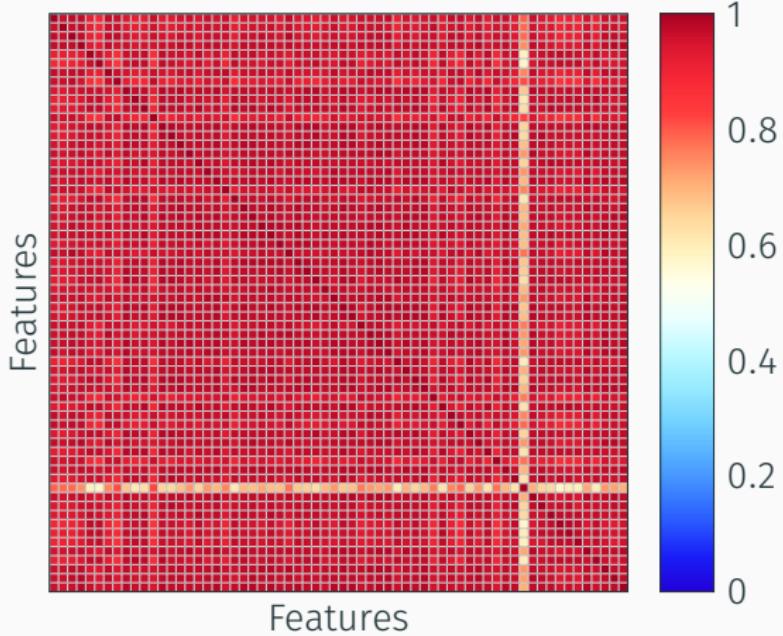
Tan, T. W. K., Nguyen, K. N., Zhang, C., Kong, R., Cheng, S. F., Ji, F., ... & B. T. Thomas Yeo. (2024). "Evaluation of Brain Age as a Specific Marker of Brain Health". *bioRxiv*, 2024-11.



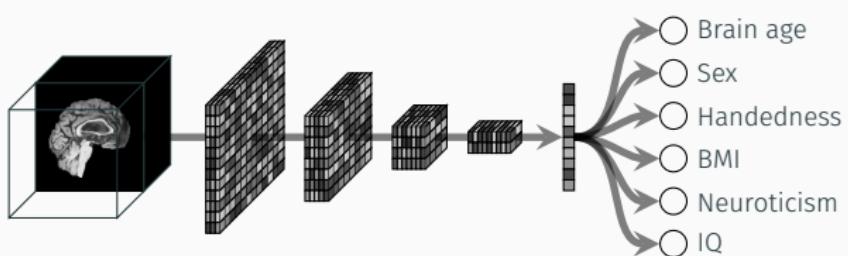
Multitask pretraining



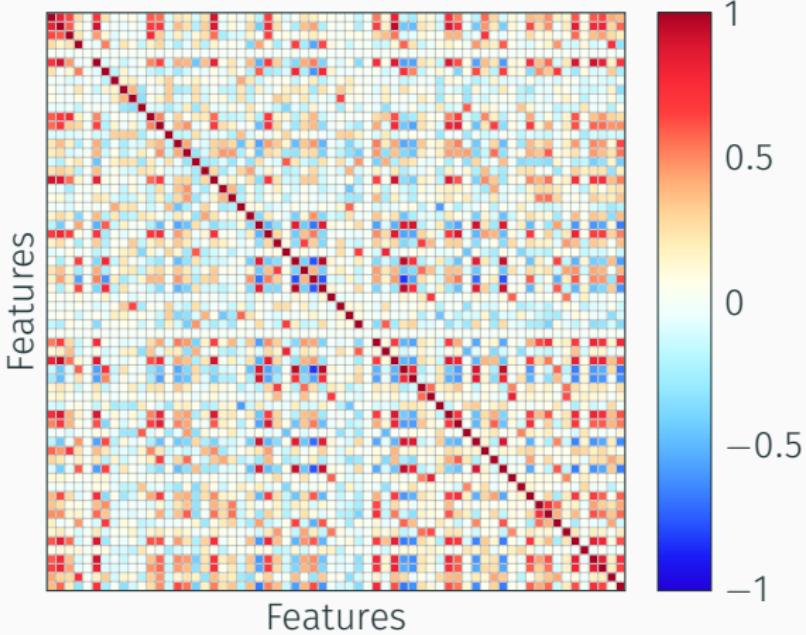
Multitask pretraining



Multitask pretraining



Multitask pretraining



Multitask pretraining



Brain age predictions



Multitask pretraining



Brain age transfer learning



Multitask pretraining



AD transfer learning



Explainable brain age predictions

