

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

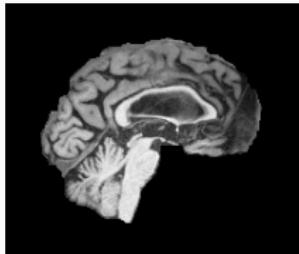


Do we need new imaging phenotypes?



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Do we need new imaging phenotypes



Do we need new imaging phenotypes

"What I cannot create, I do not understand."

- Richard Feynman



Do we need new imaging phenotypes

predict

"What I cannot create, I do not understand."



Do we need new imaging phenotypes

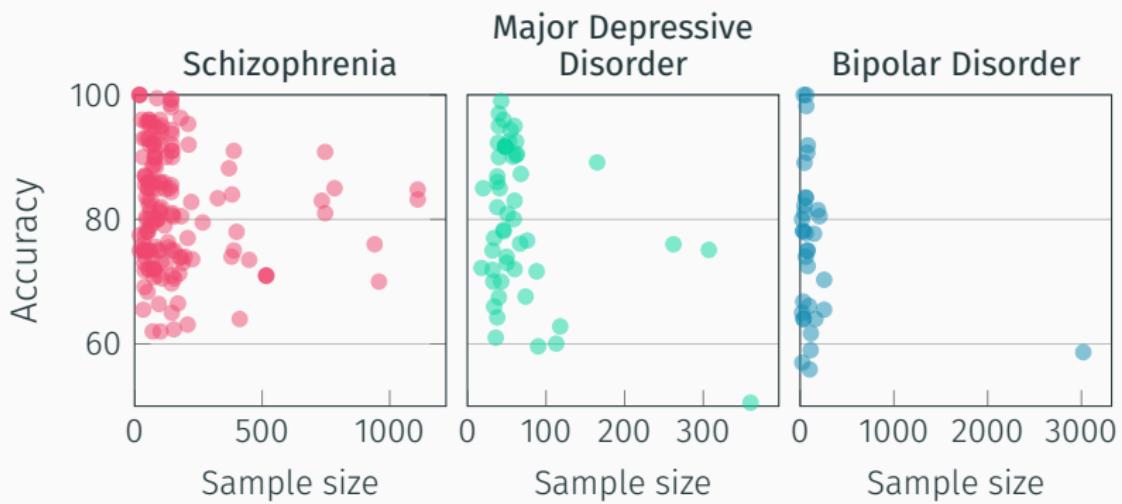
predict

"What I cannot create, I do not understand."

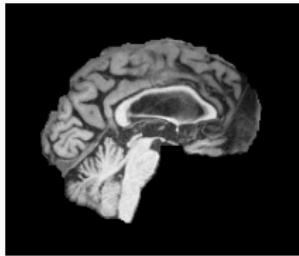
(or I should at least be able to explain why I can't predict it)



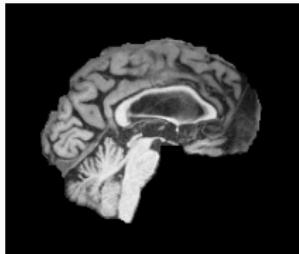
Do we need new imaging phenotypes



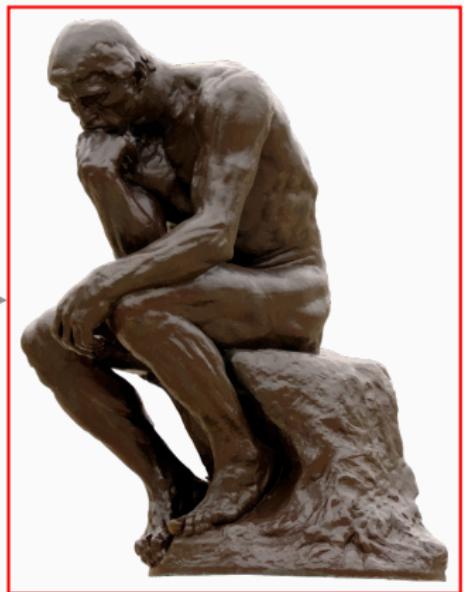
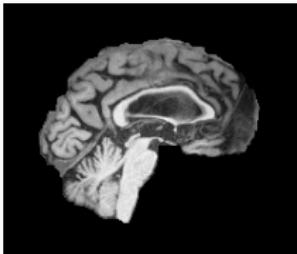
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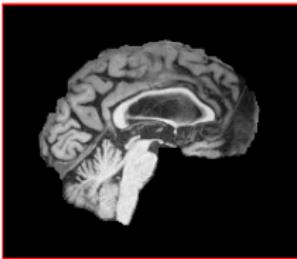
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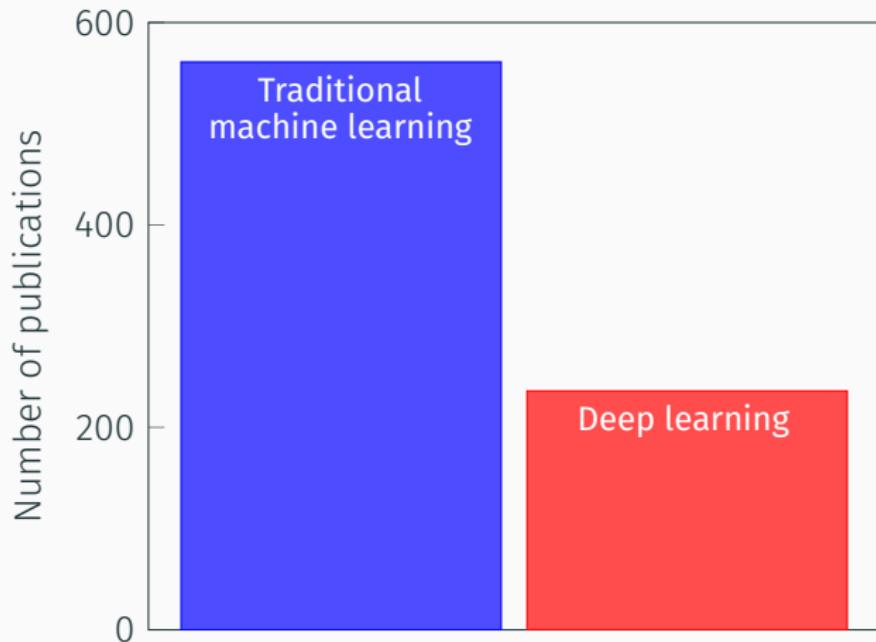
Do we need new imaging phenotypes



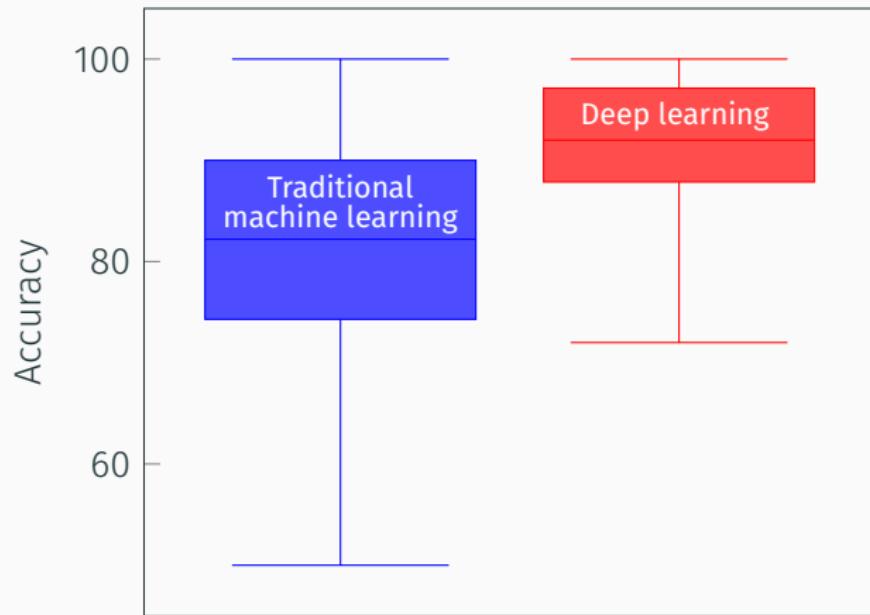
Do we need new imaging phenotypes



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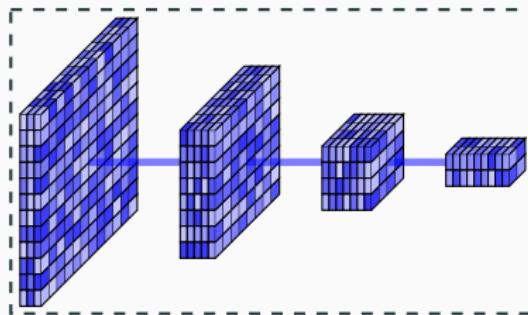
How can we find new phenotypes with AI?



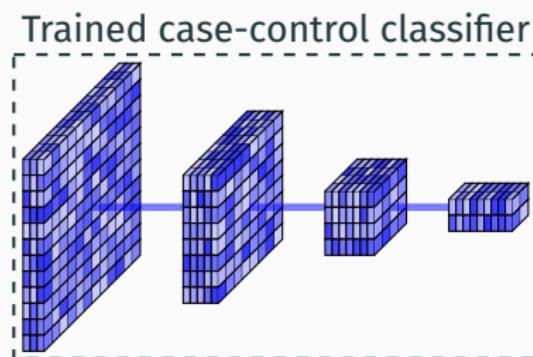
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What does neural networks do?

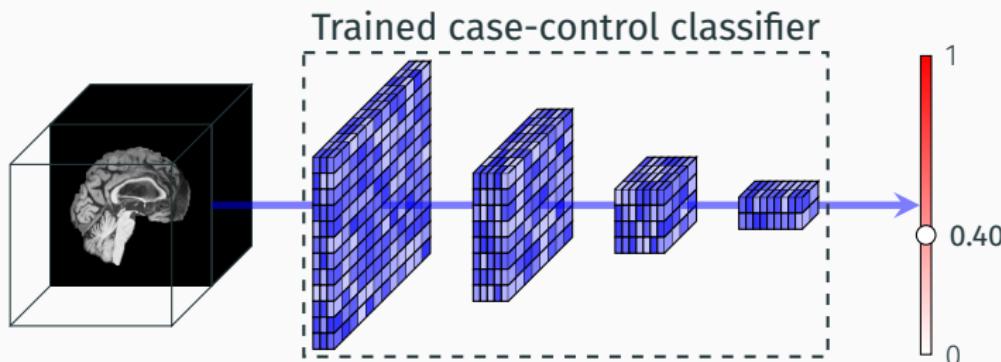
Convolutional neural network



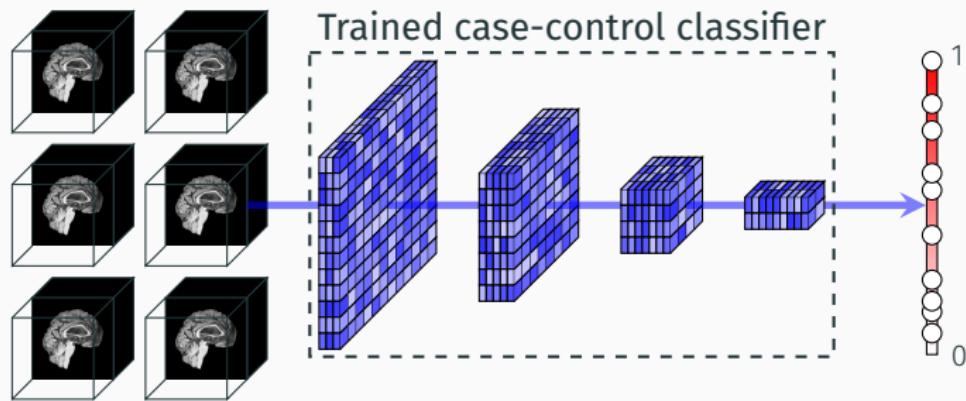
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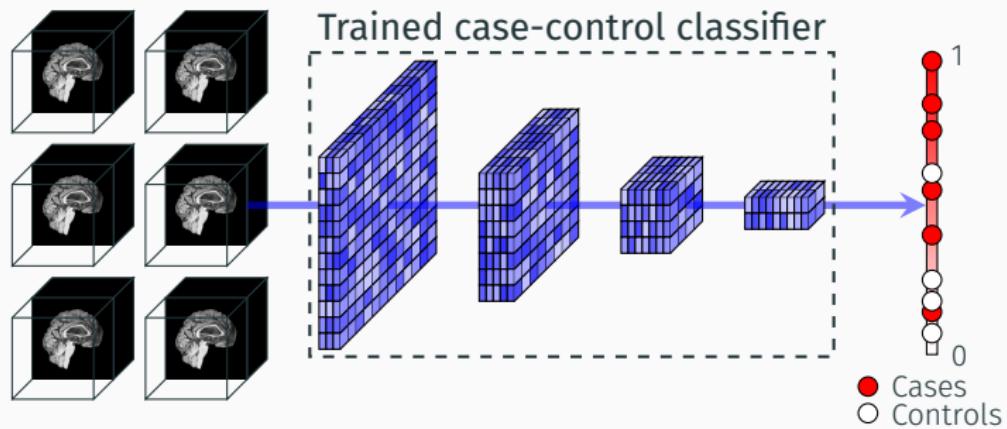
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What does neural networks do?

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



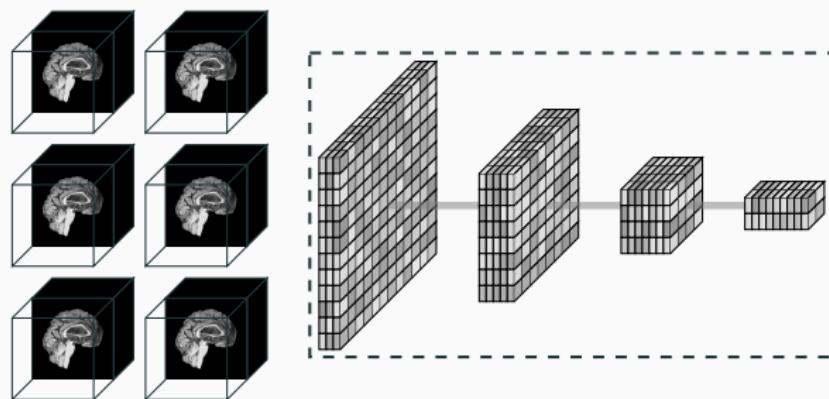
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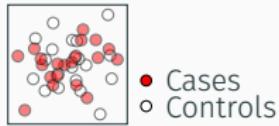
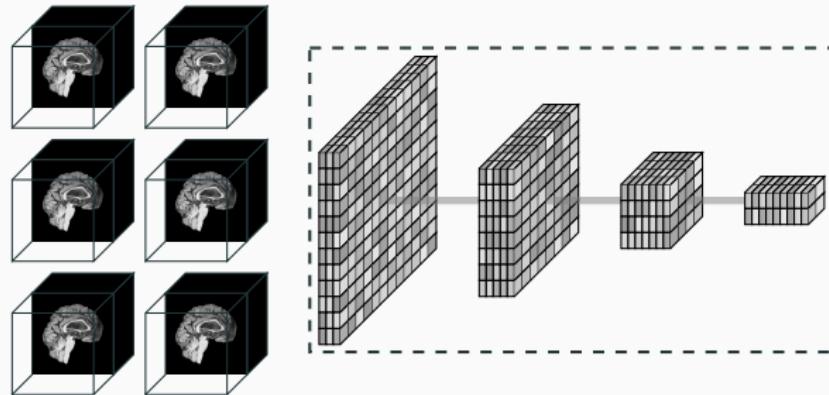

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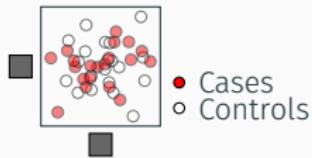
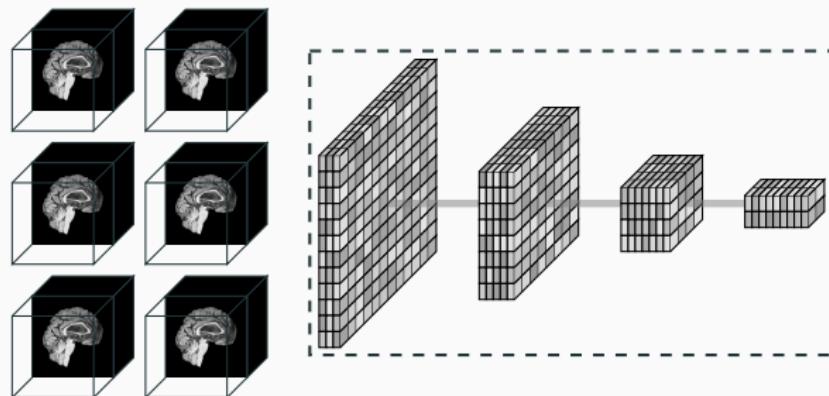

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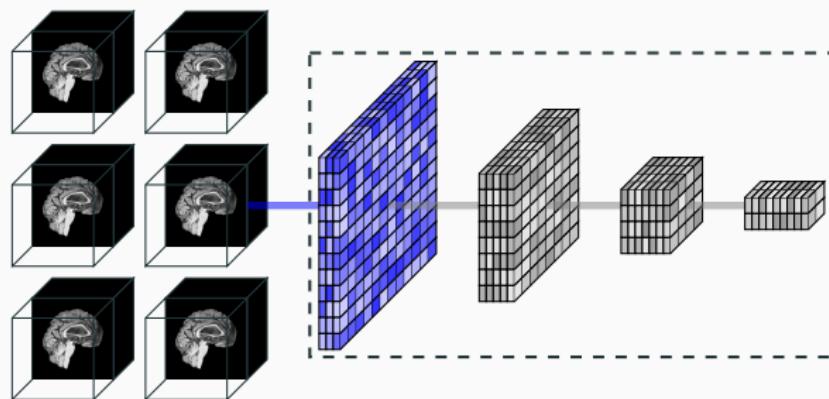
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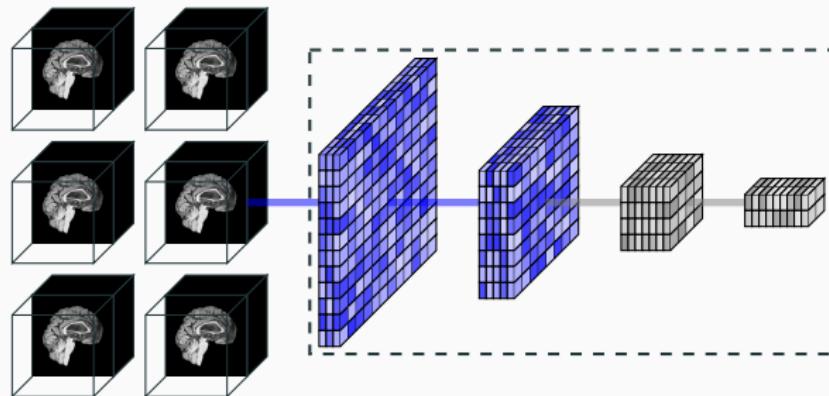
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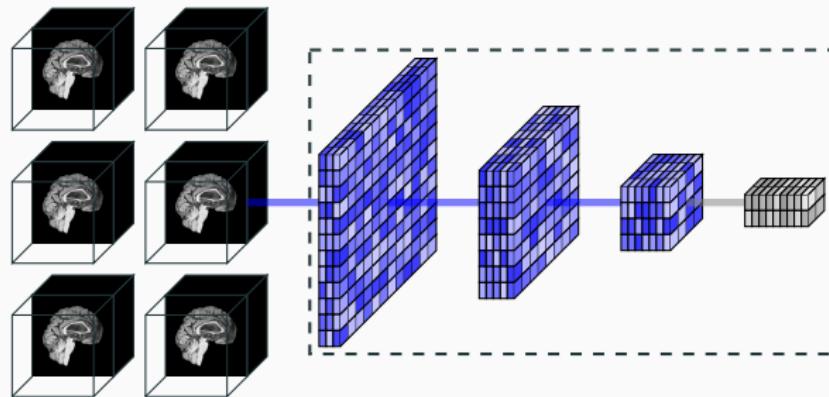
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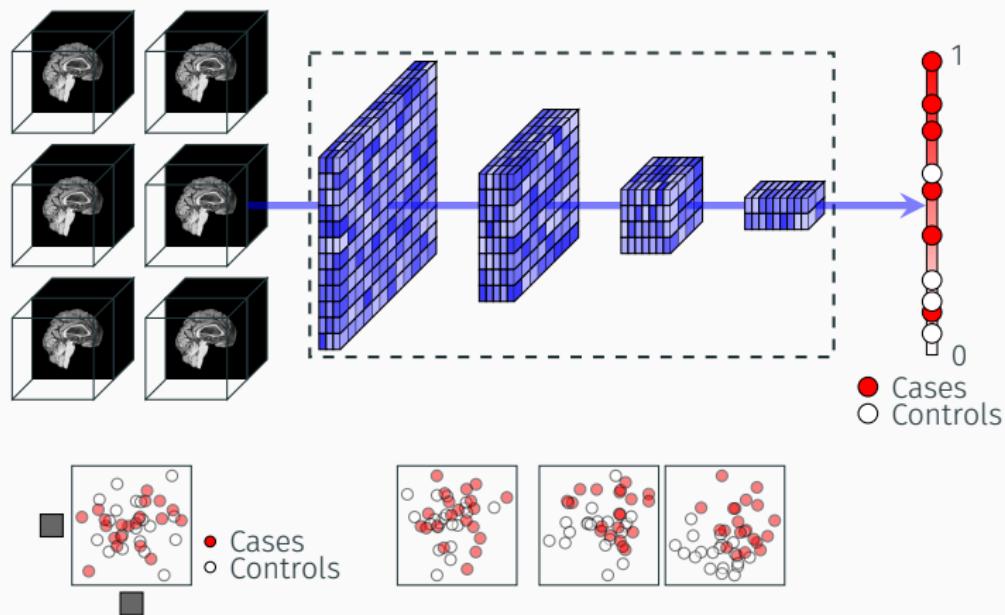
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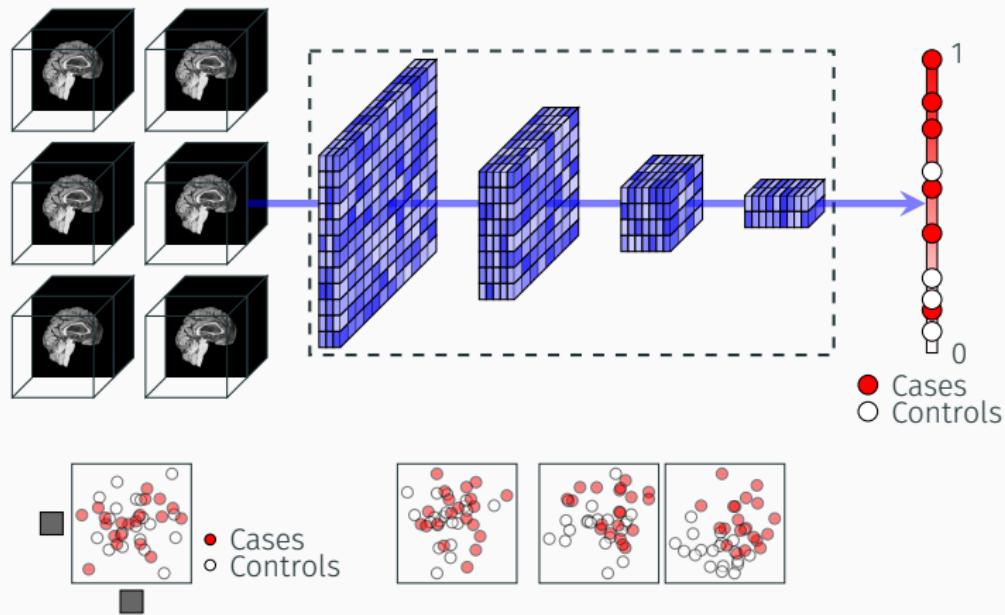
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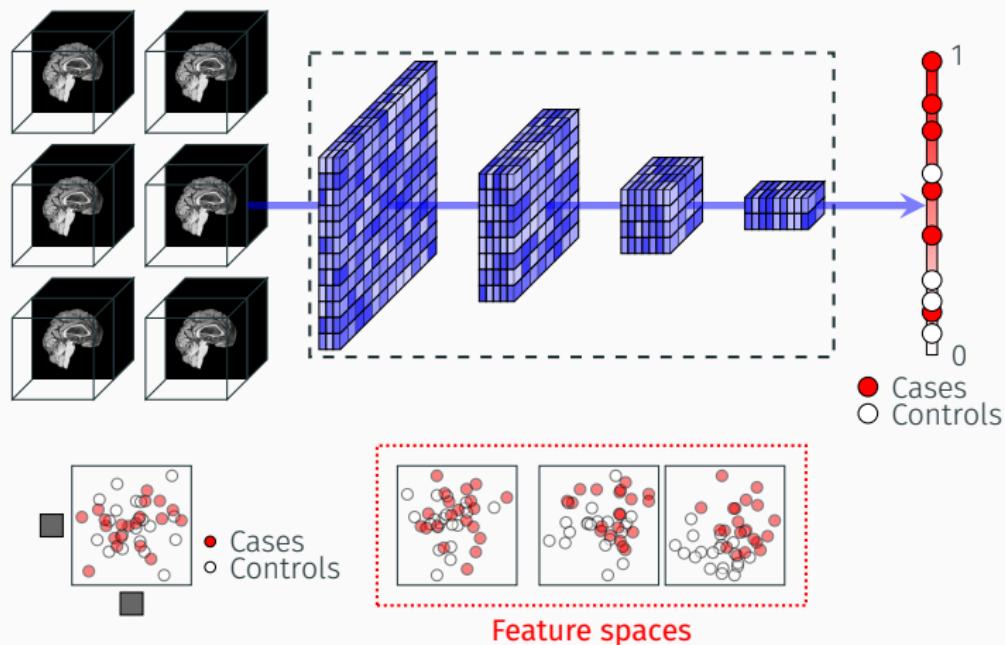
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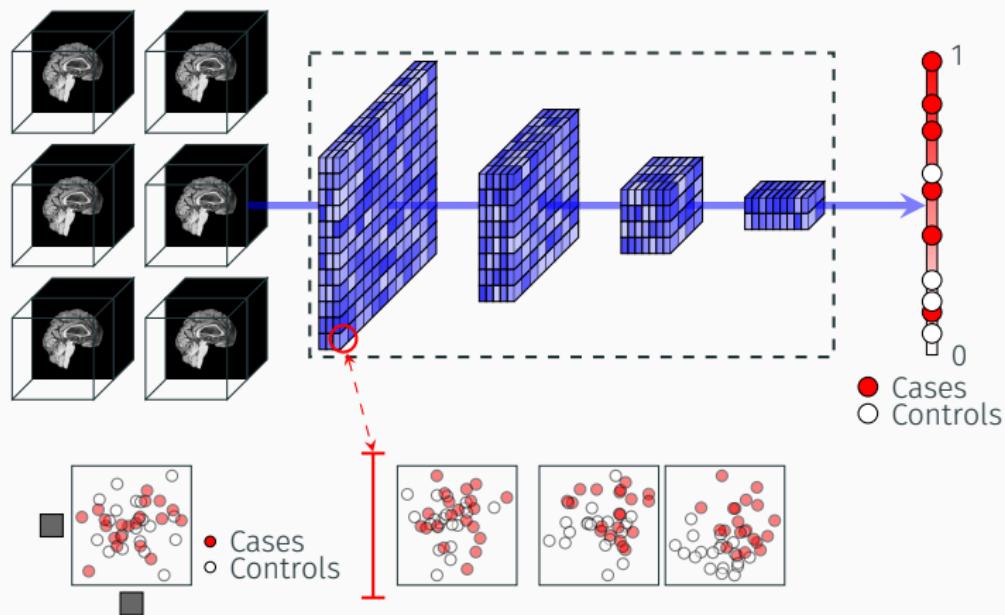
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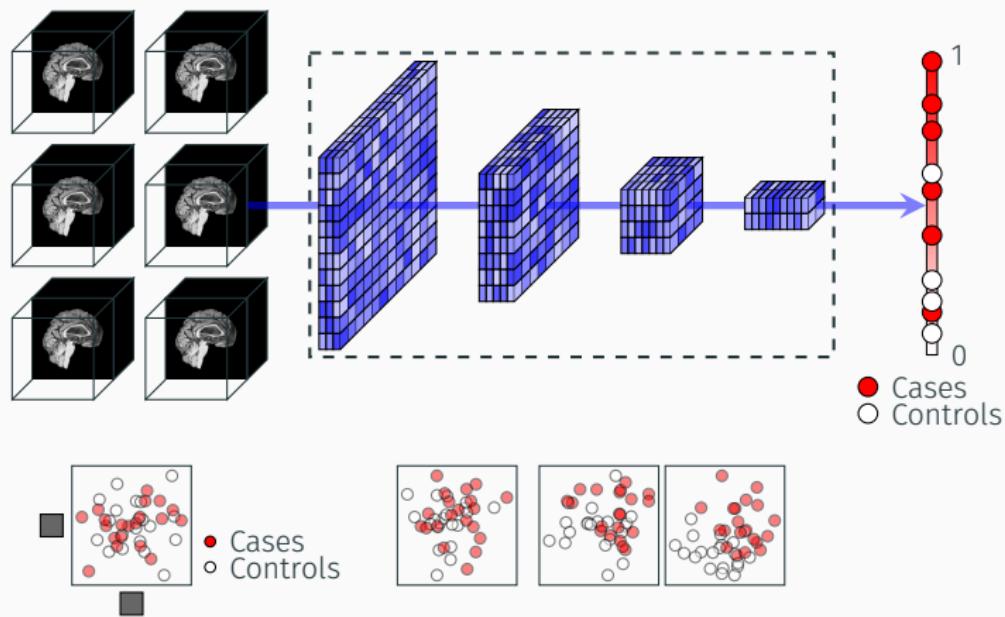
What does neural networks do?



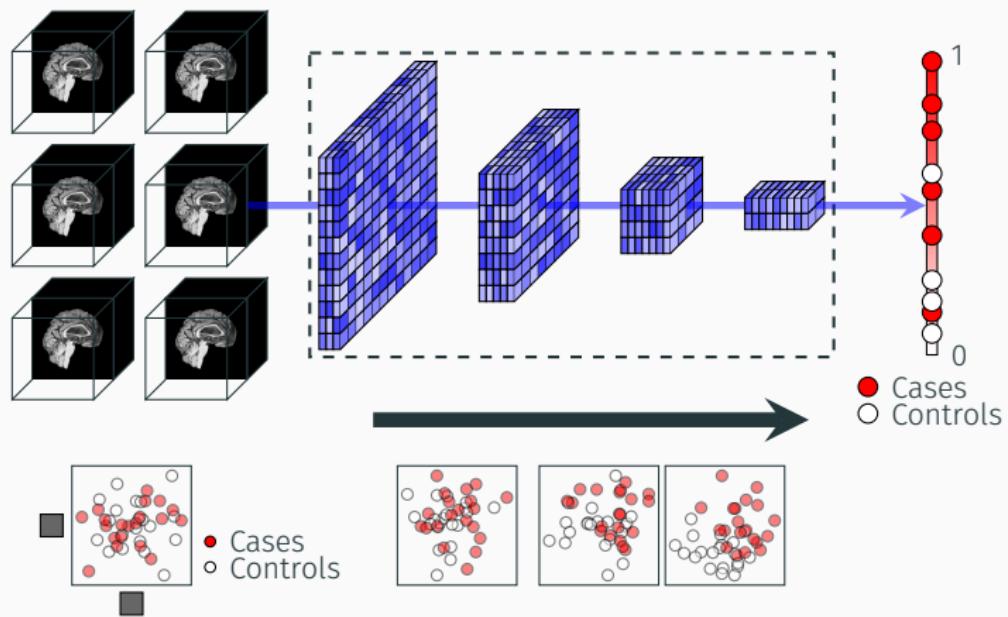
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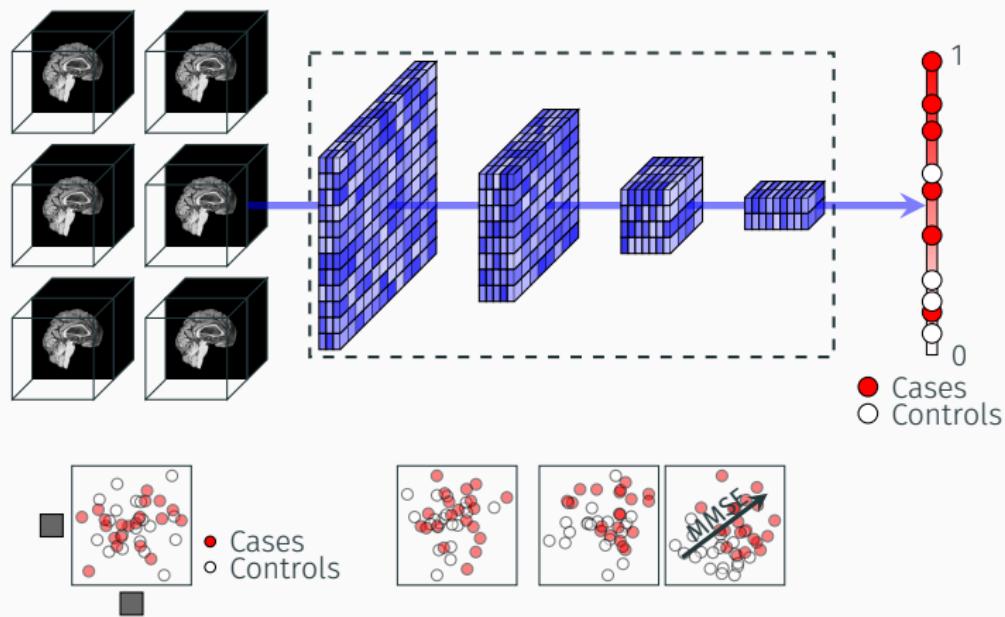
What does neural networks do?



What does neural networks do?



What does neural networks do?



How can we understand these features?



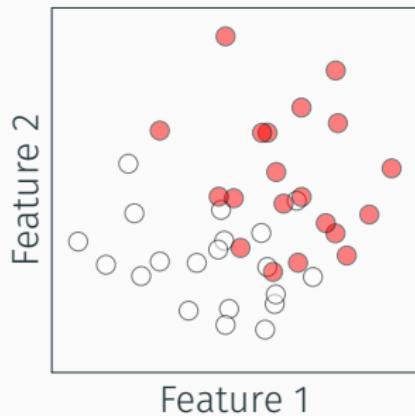
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How can we understand these learned features?

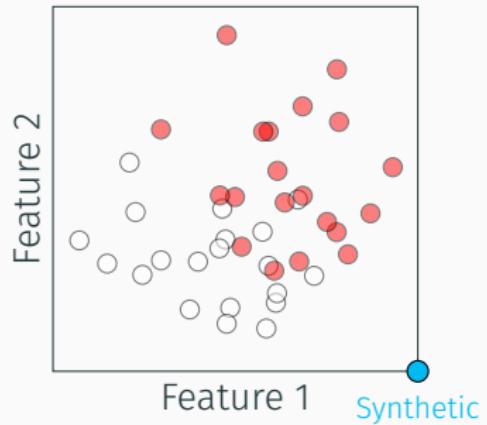
Explainable AI!



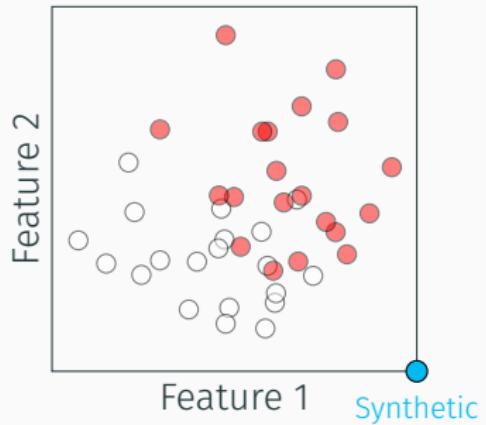
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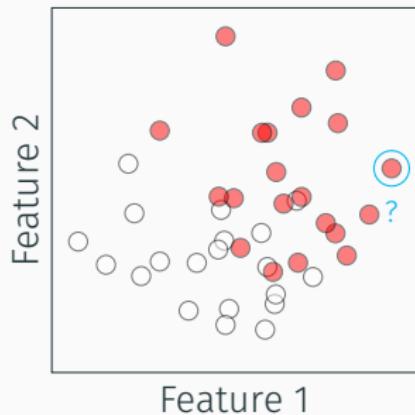
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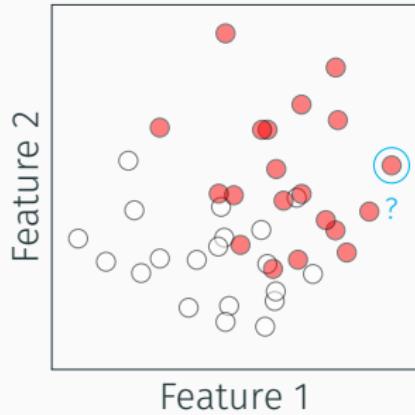
Activation maximization



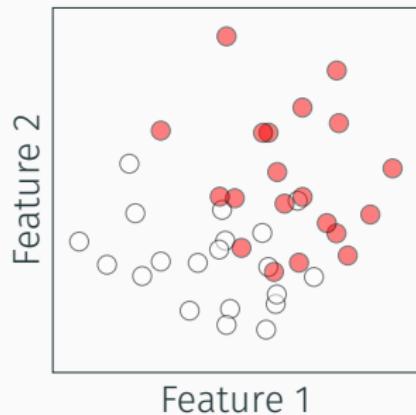
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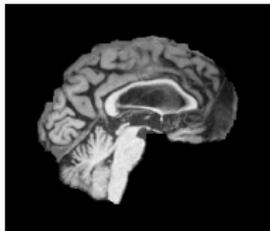
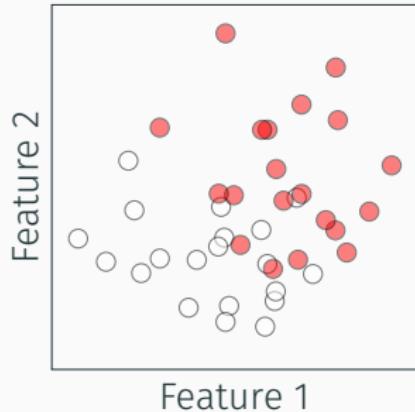
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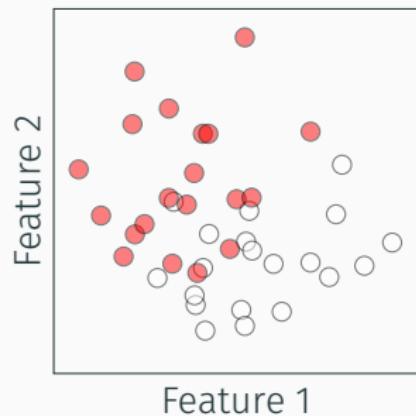
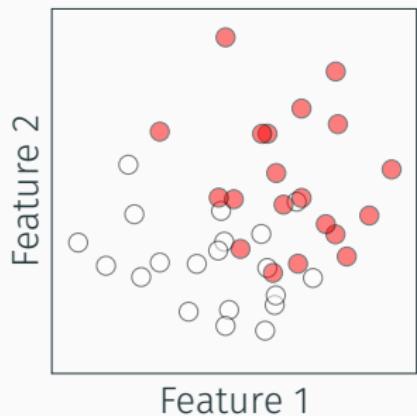
How can we understand these learned features?



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



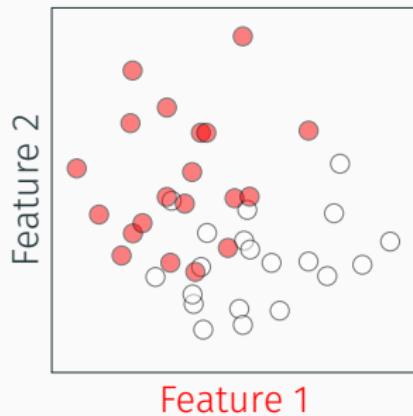
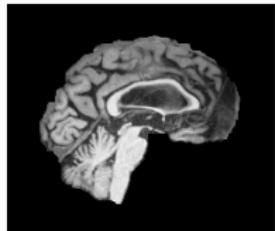
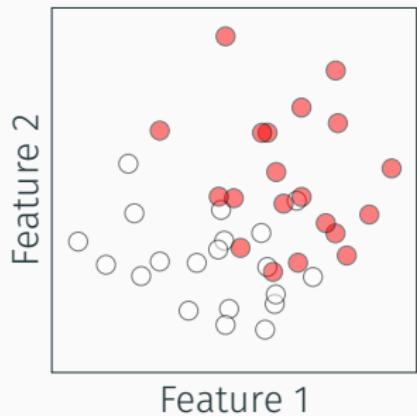
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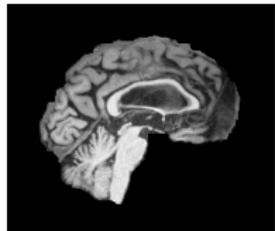
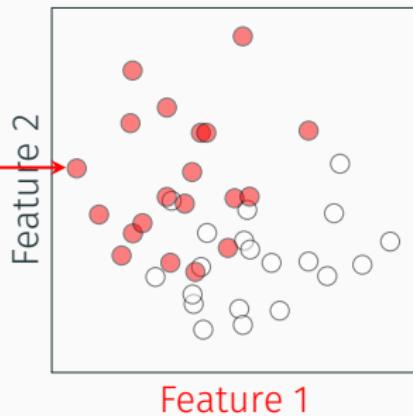
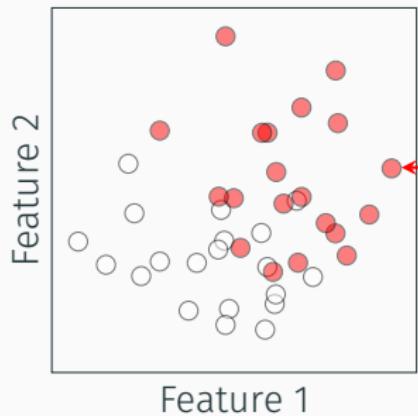
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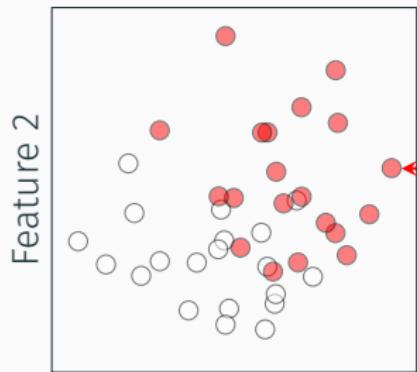
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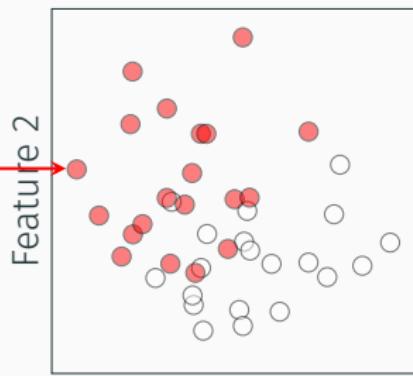
The patient shows
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How can we understand these learned features?



Cortical atrophy



Feature 1

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

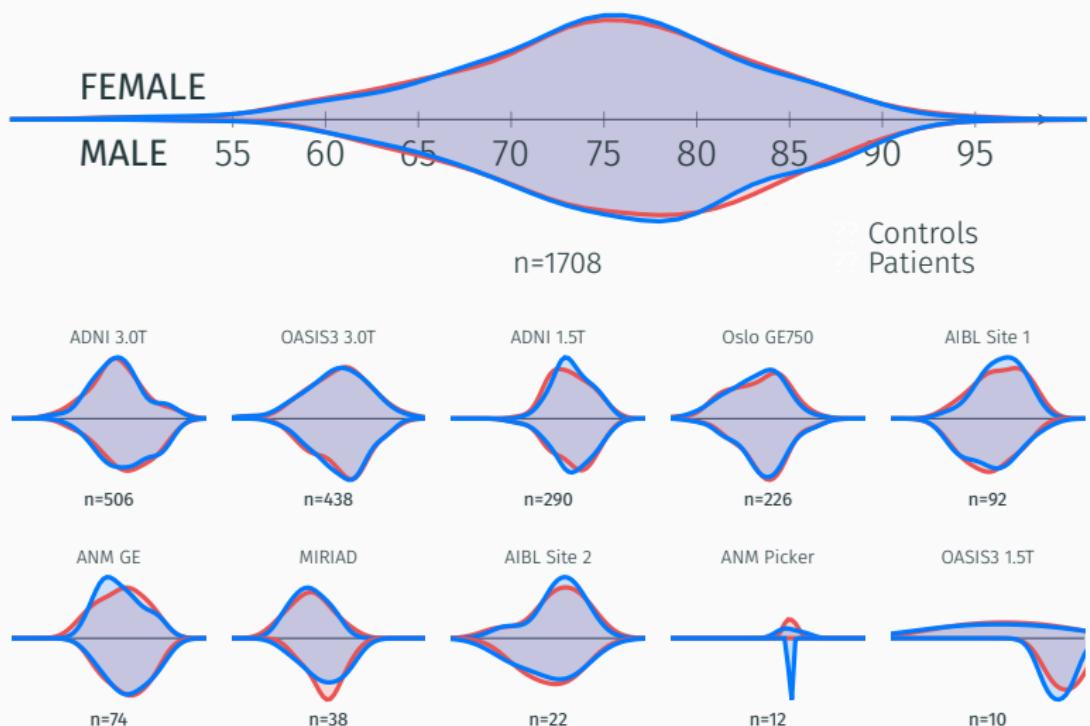


Use case: Dementia and XAI

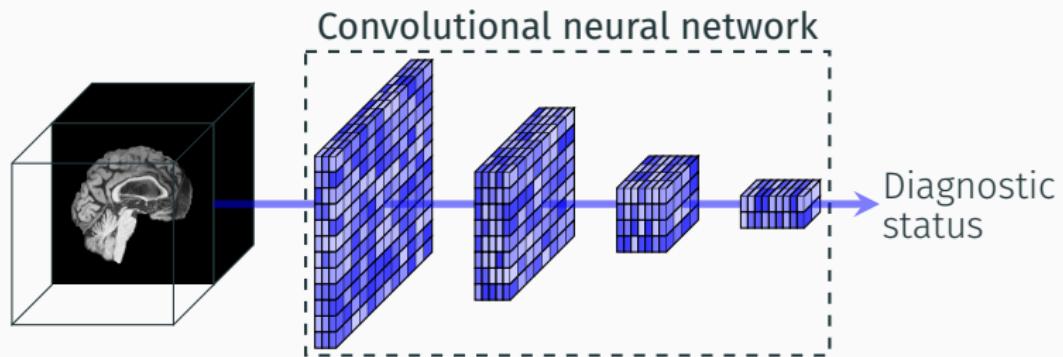


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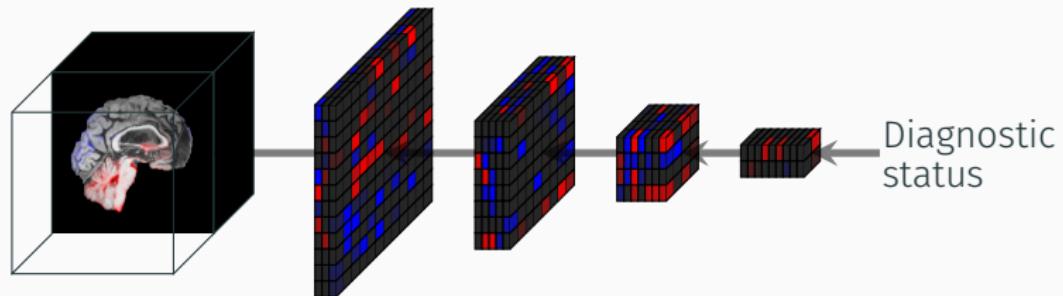
Dementia and explainable AI



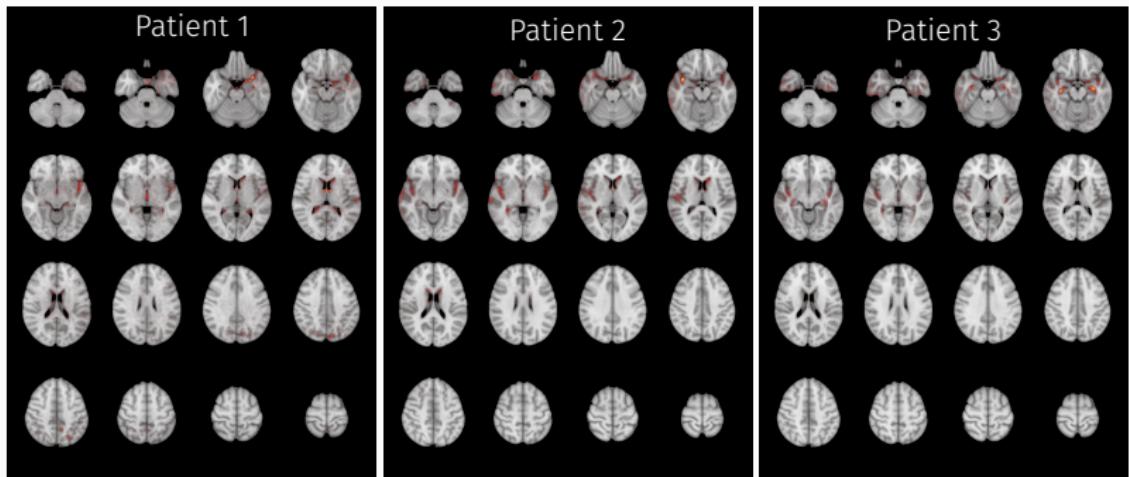
Dementia and explainable AI



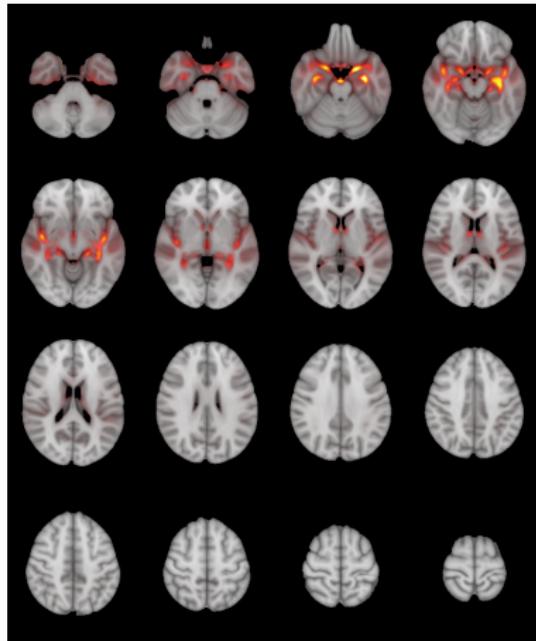
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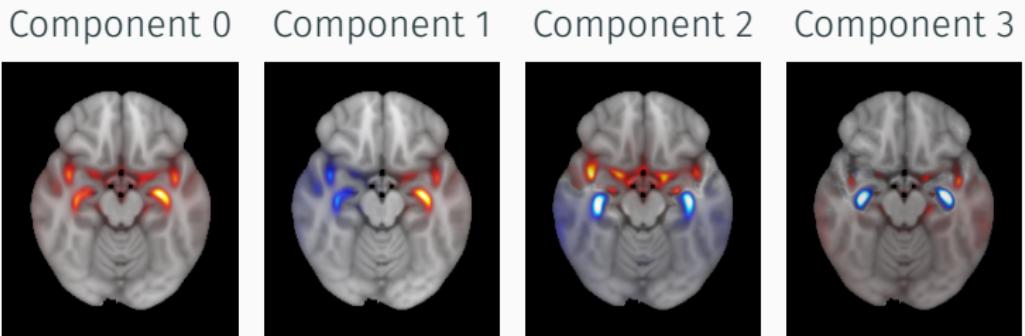
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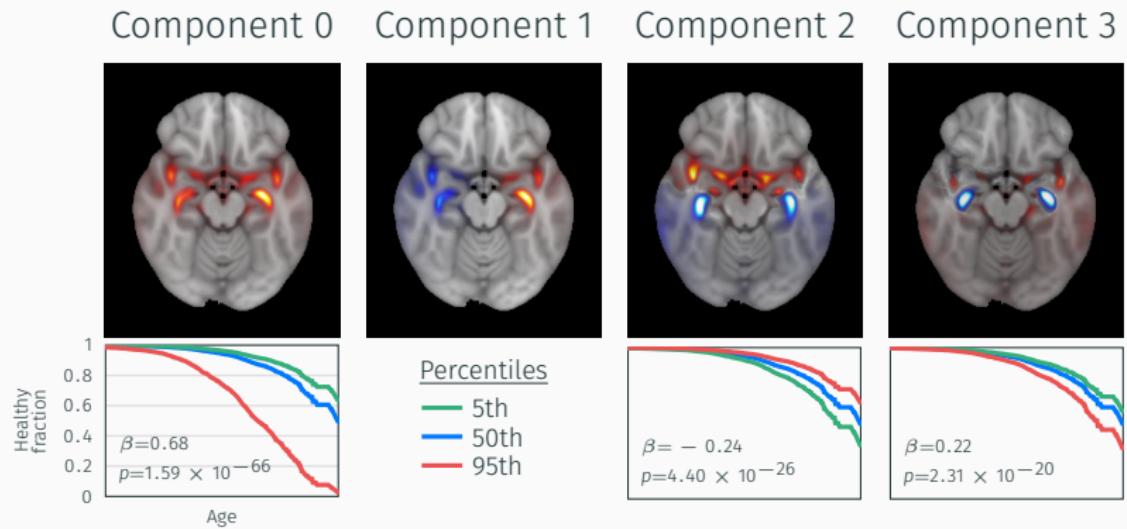
Dementia and explainable AI



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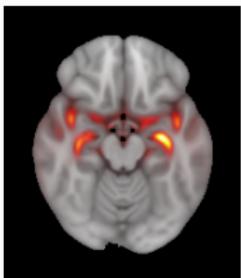


Dementia and explainable AI

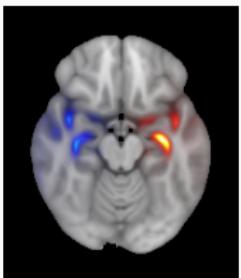


Dementia and explainable AI

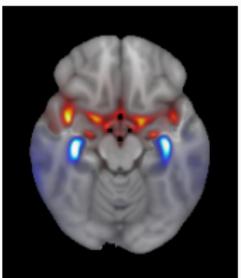
Component 0



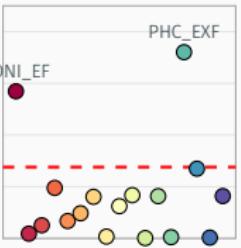
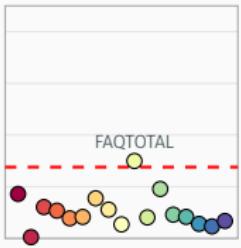
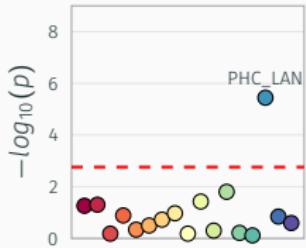
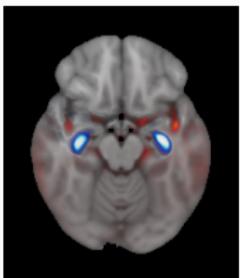
Component 1



Component 2



Component 3

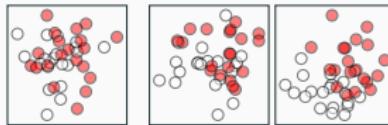
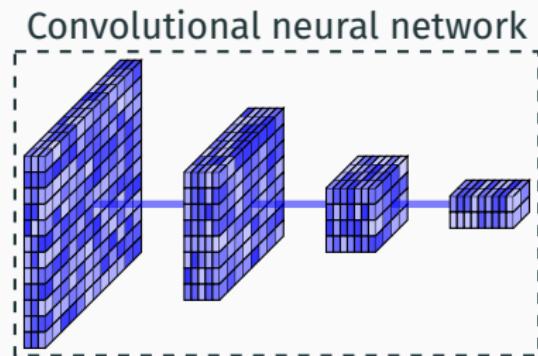


Multitask pretraining

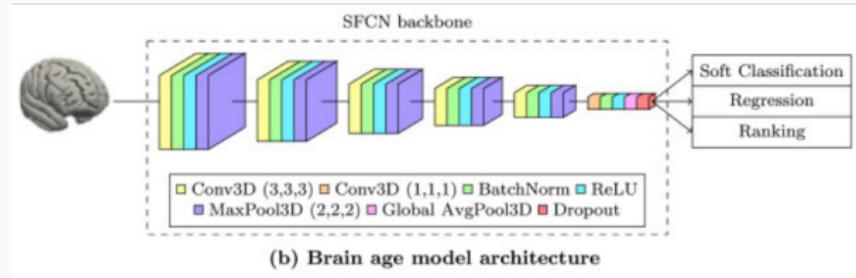


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Multitask pretraining



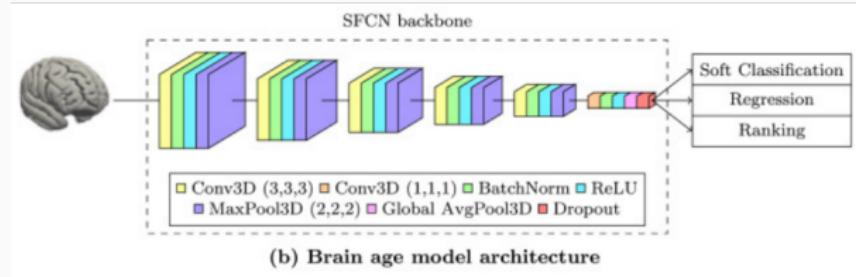
Multitask pretraining



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



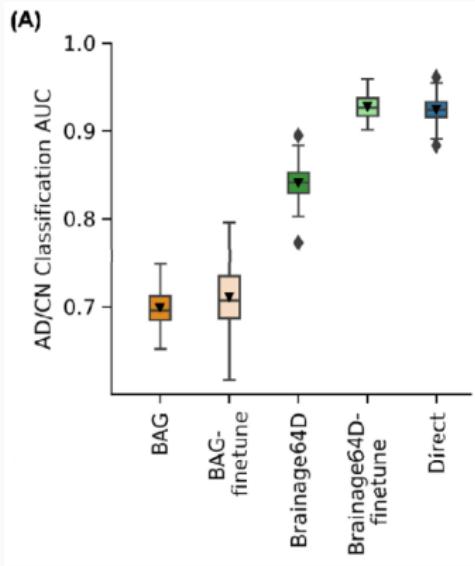
"Furthermore, we see this result as evidence that deep learning models trained to predict age in large multisite datasets constitute excellent starting points for transfer learning, which can subsequently be fine-tuned to a variety of tasks."

- 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.



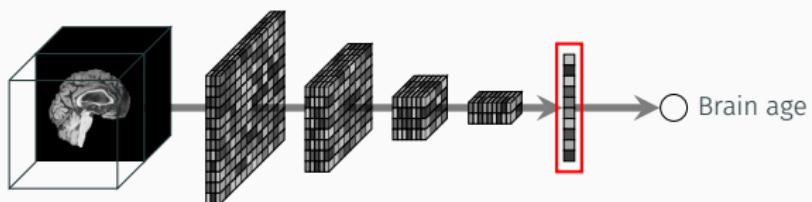
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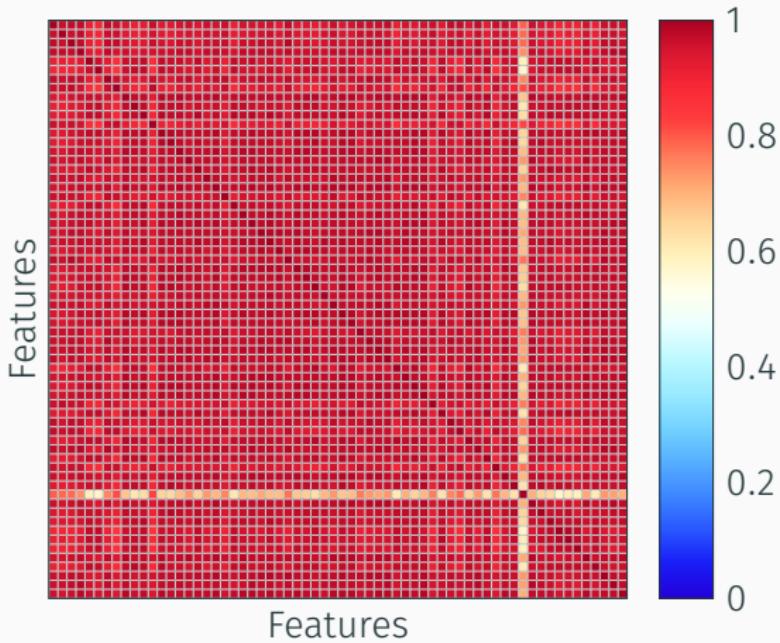
Tan, T. W. K., Nguyen, K. N., Zhang, C., Kong, R., Cheng, S. F., Ji, F., ... & B. T. Thomas Yeo. (2024). "Evaluation of Brain Age as a Specific Marker of Brain Health". *bioRxiv*, 2024-11.



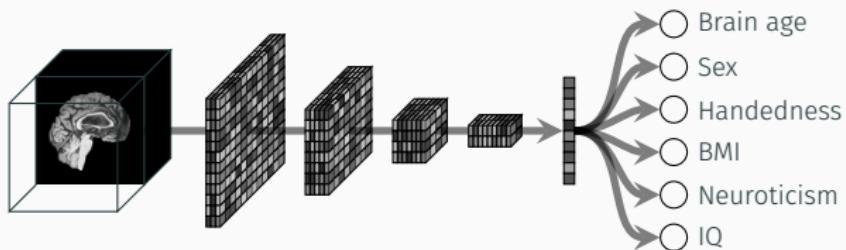
Multitask pretraining



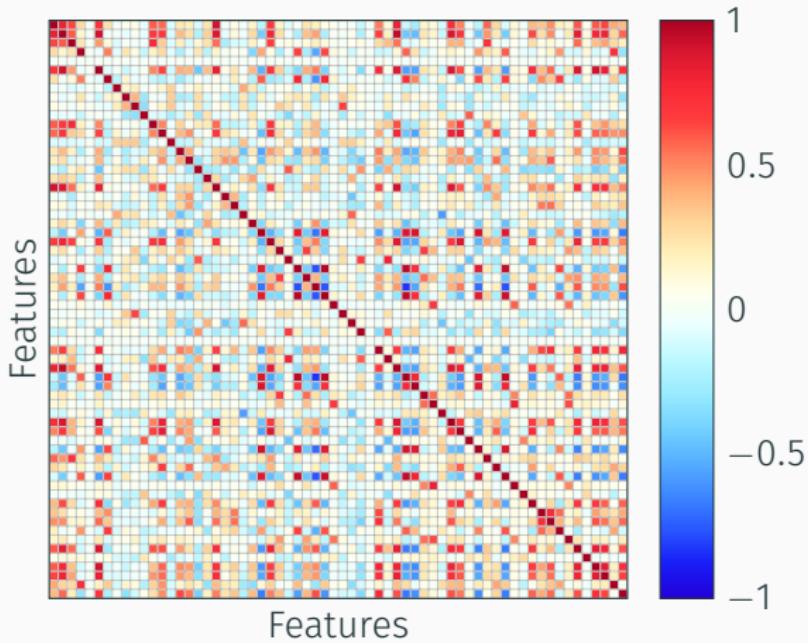
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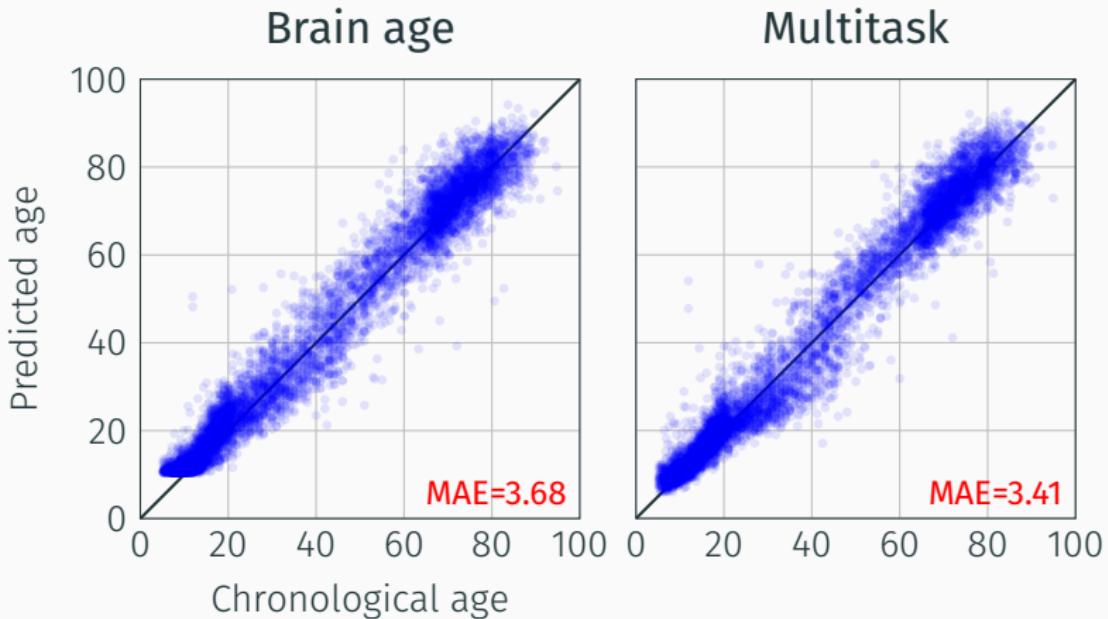
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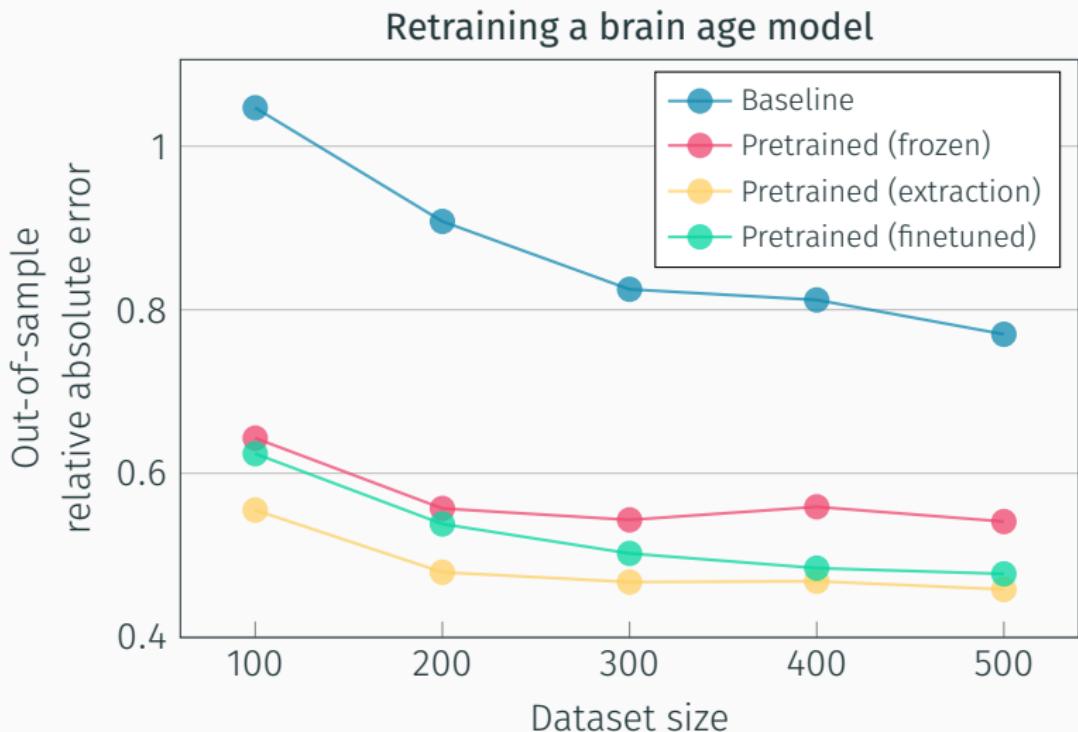
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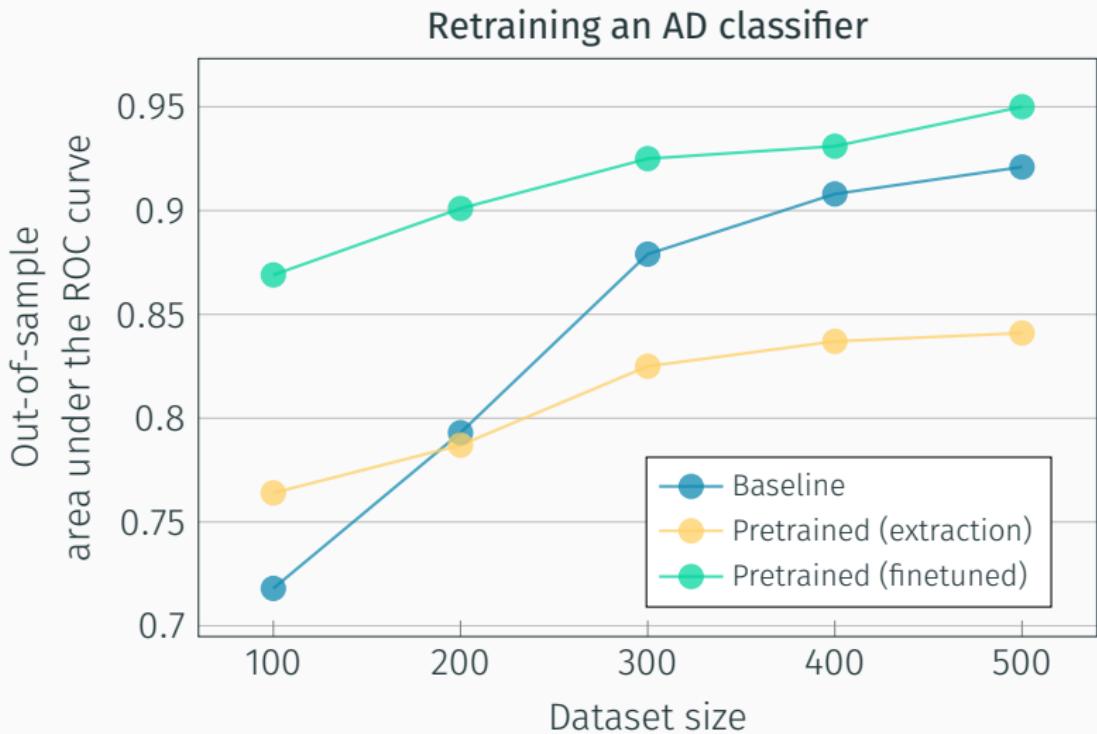
Multitask pretraining



Multitask pretraining



Multitask pretraining



Use case: Explainable brain age

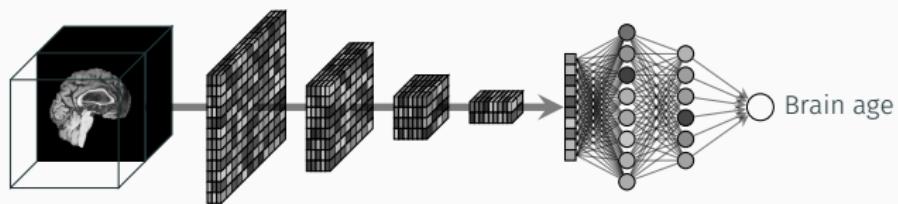


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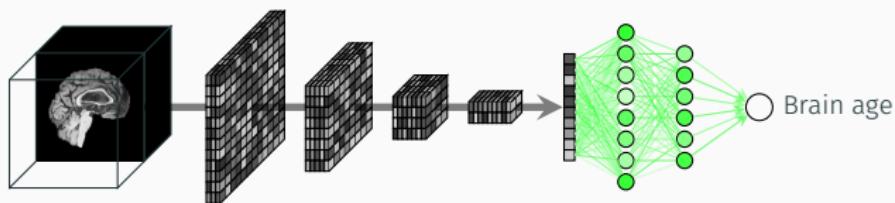
Explainable brain age predictions



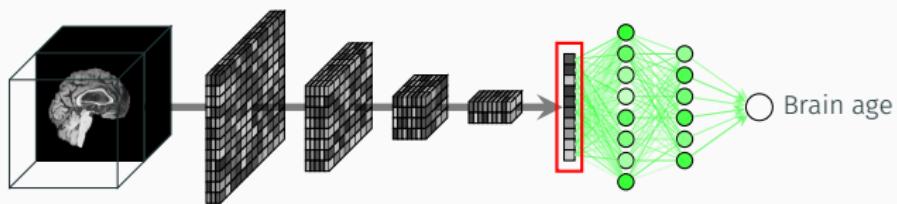
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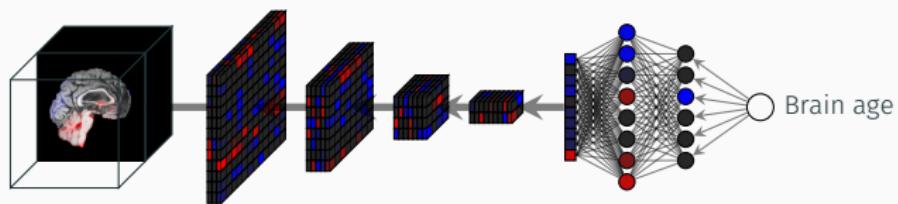
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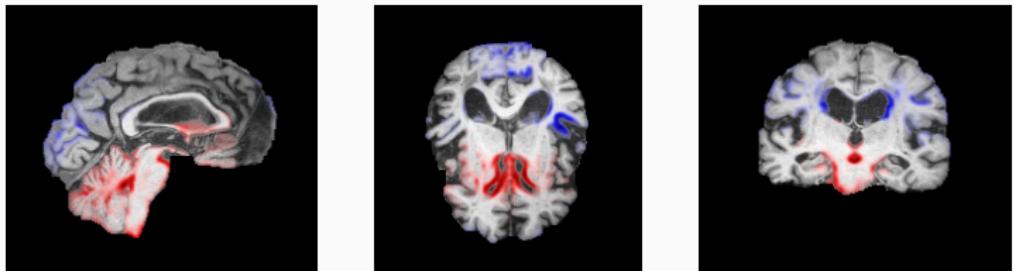
Explainable brain age predictions



Explainable brain age predictions



Explainable brain age predictions

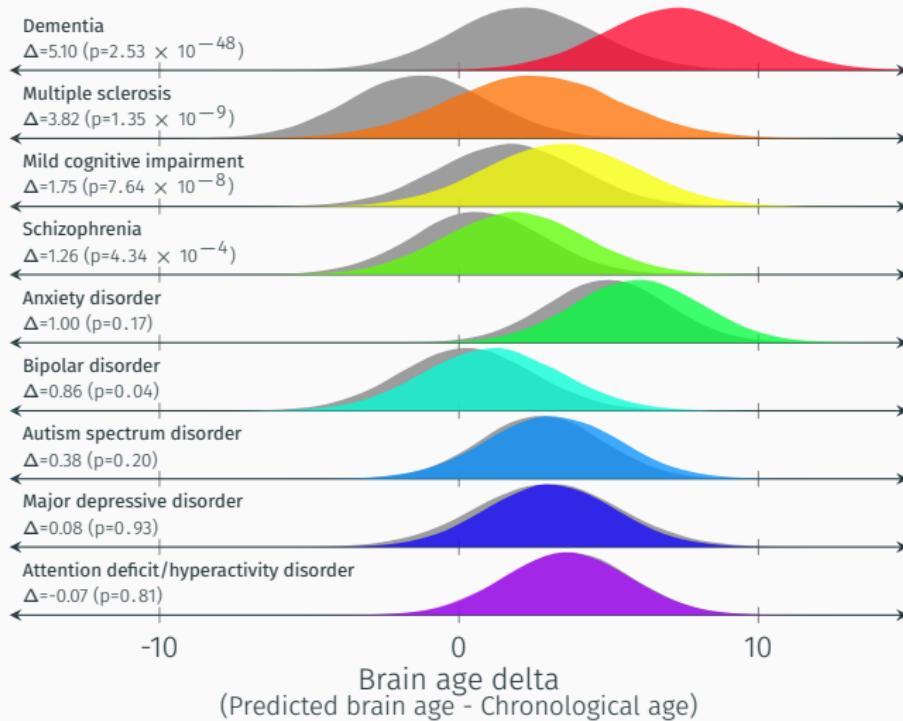


Younger
appearing

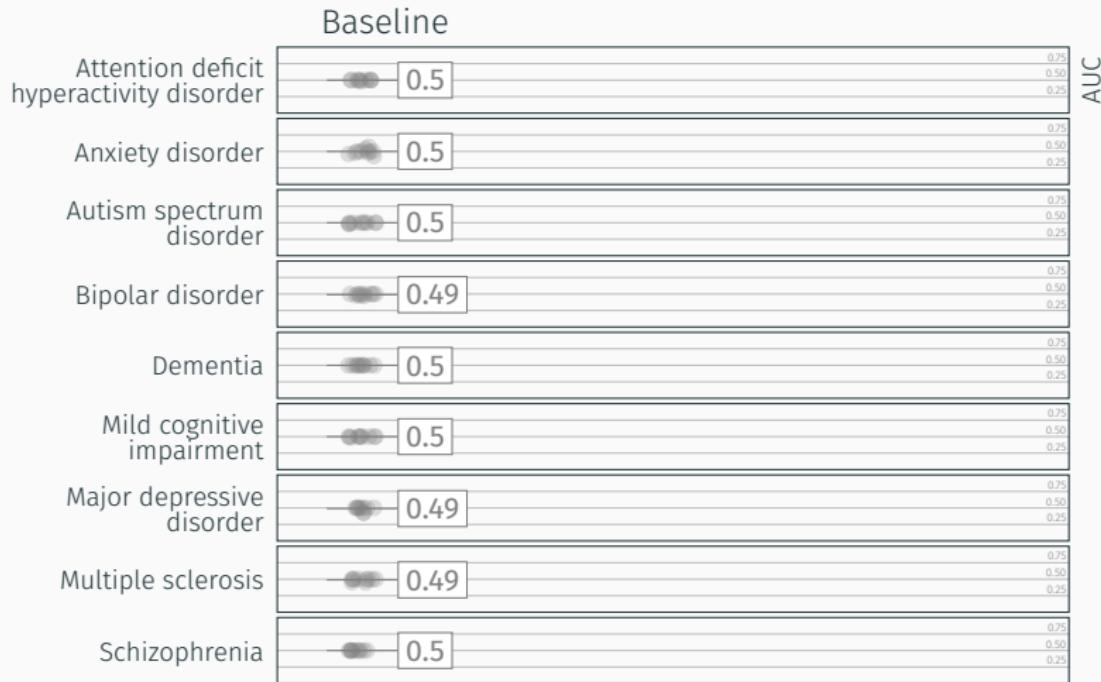
Older
appearing



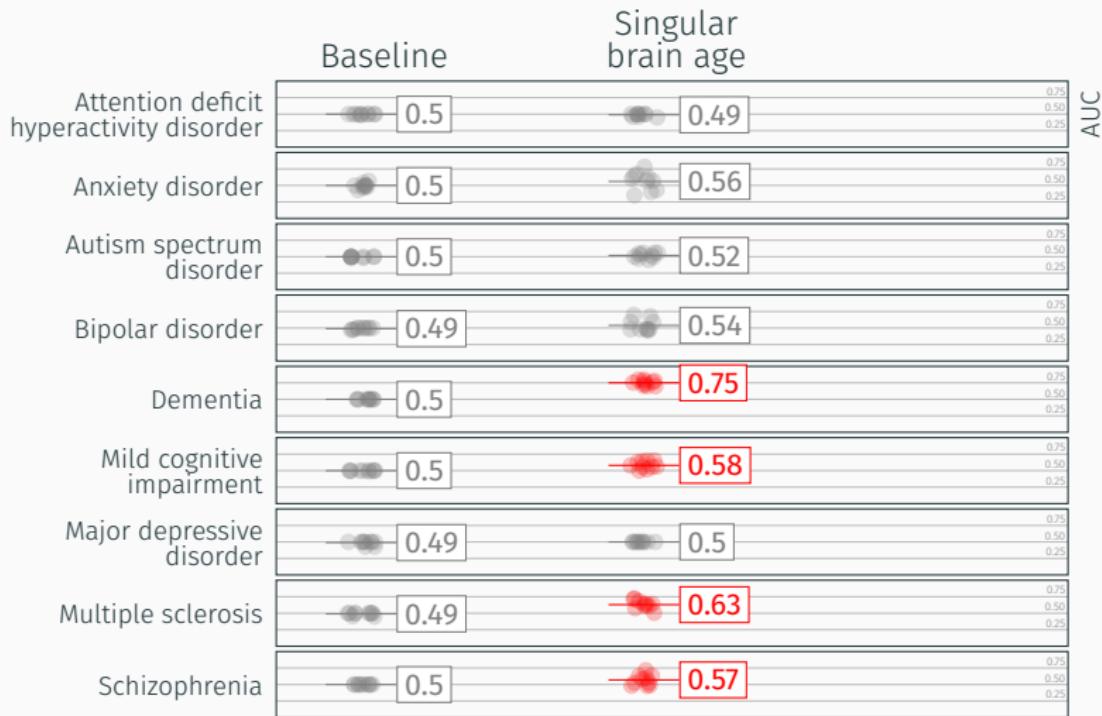
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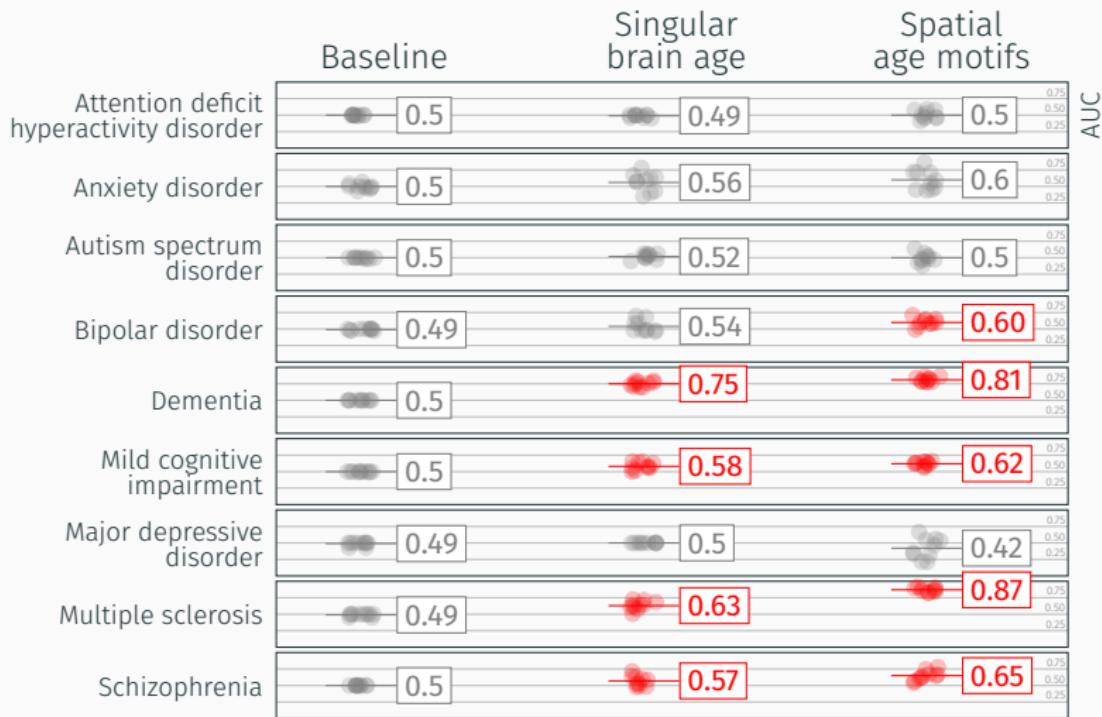
Explainable brain age predictions



Explainable brain age predictions



Explainable brain age predictions



Thank you!



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