

Artificial Intelligence in Healthcare

Identifying neuroimaging phenotypes with AI

Esten H. Leonardsen

07.02.25



UNIVERSITY
OF OSLO

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?



UNIVERSITY
OF OSLO

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

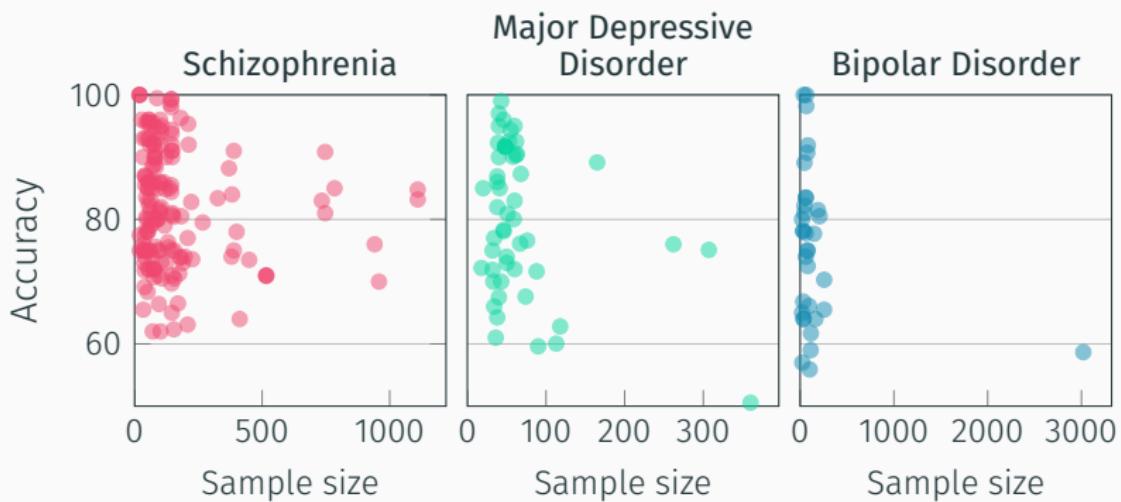
predict

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

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



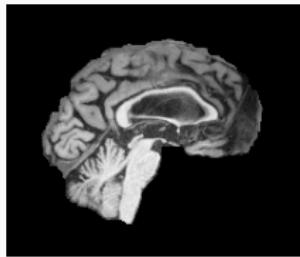
Do we need new imaging phenotypes



Do we need new imaging phenotypes



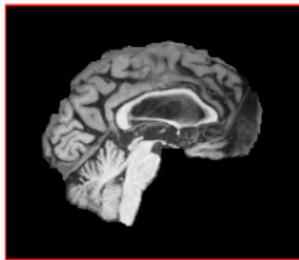
Do we need new imaging phenotypes



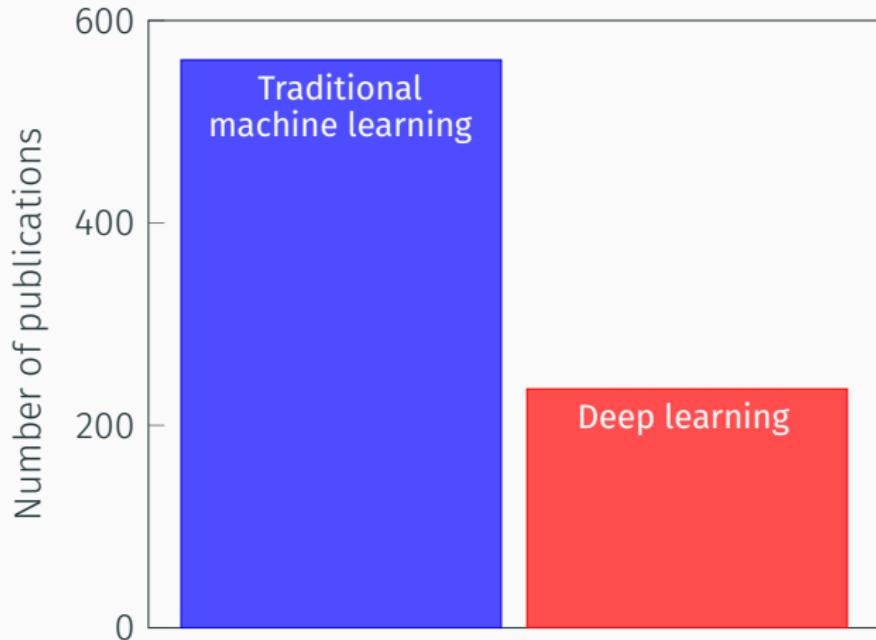
Do we need new imaging phenotypes



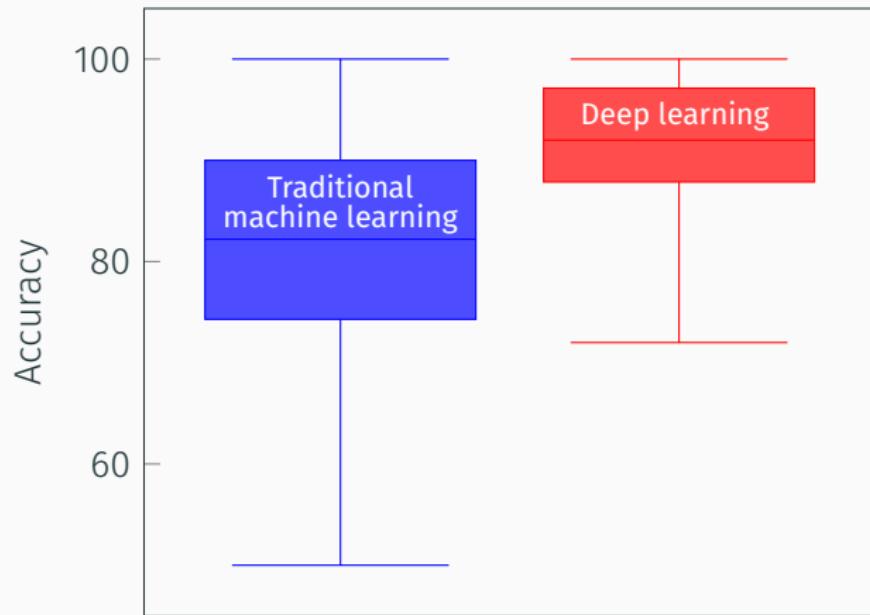
Do we need new imaging phenotypes



Do we need new imaging phenotypes



Do we need new imaging phenotypes



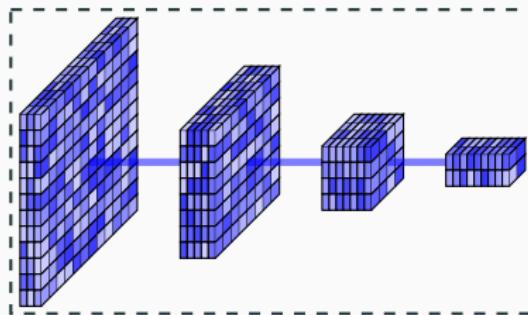
How can we find new phenotypes with AI?



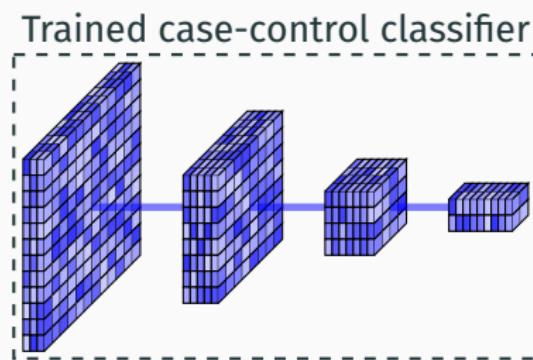
UNIVERSITY
OF OSLO

What does neural networks do?

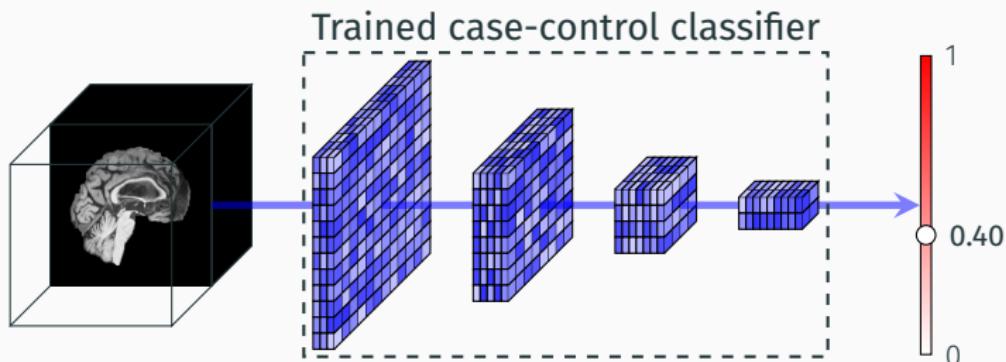
Convolutional neural network



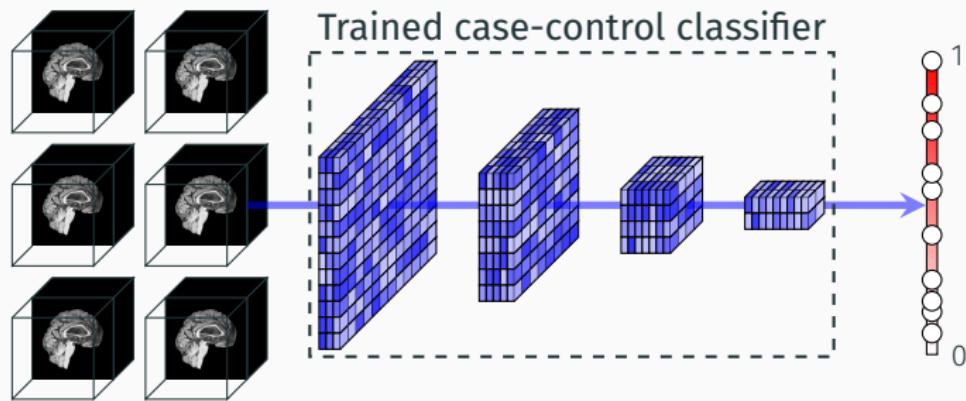
What does neural networks do?



What does neural networks do?



What does neural networks do?



What does neural networks do?



What does neural networks do?

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



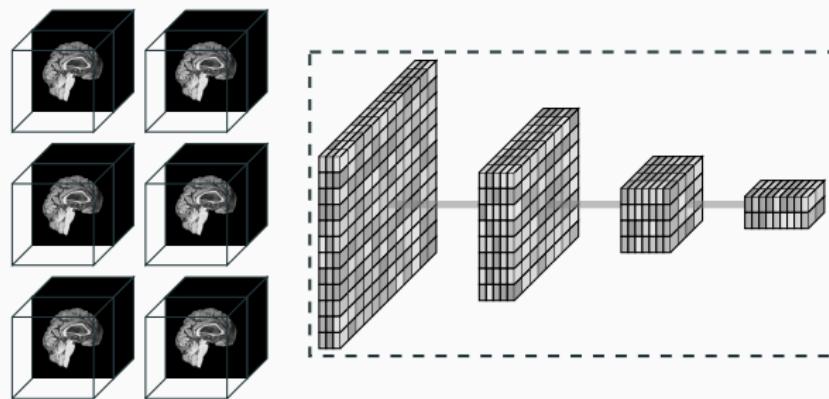
What does neural networks do?

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

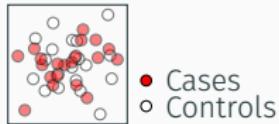
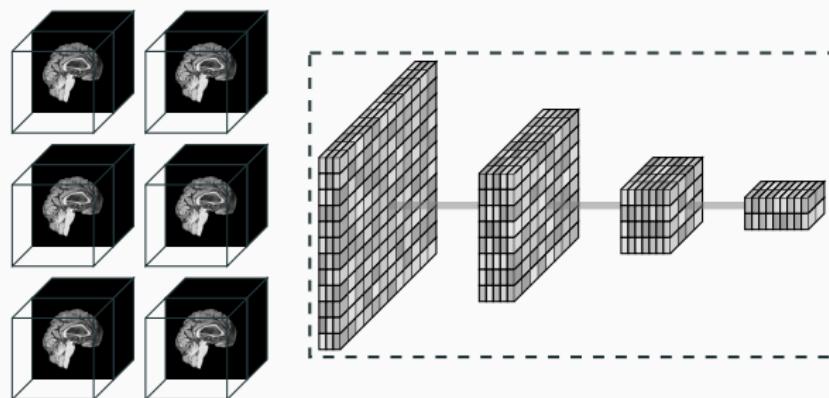

What does neural networks do?

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

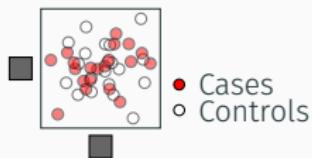
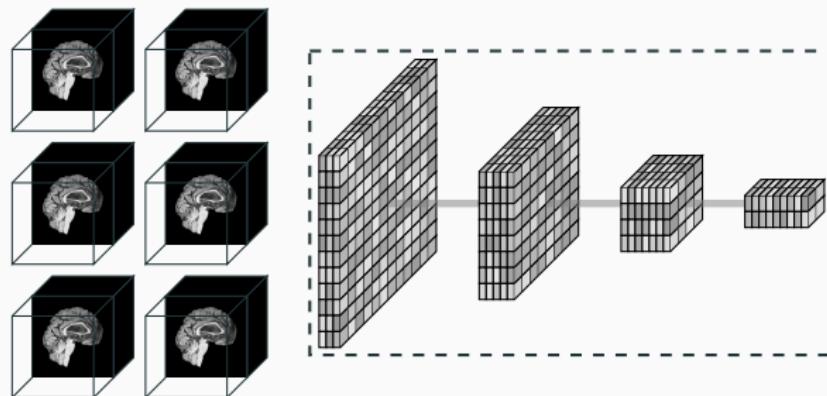

What does neural networks do?



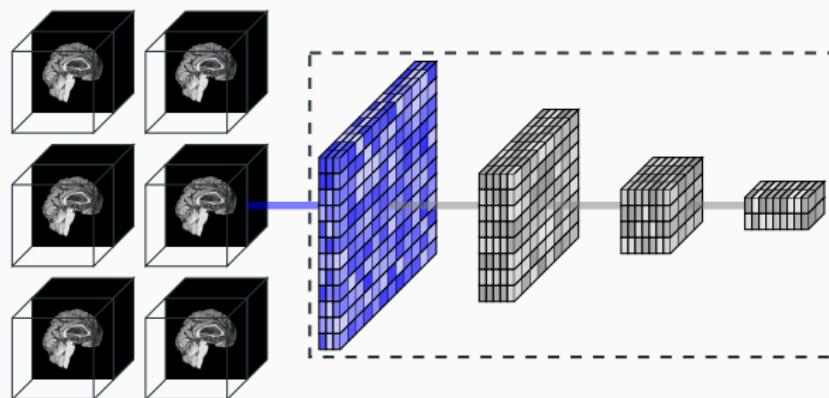
What does neural networks do?



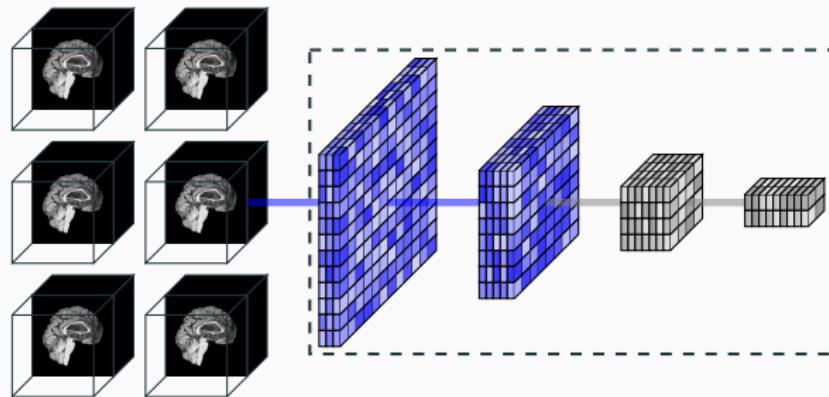
What does neural networks do?



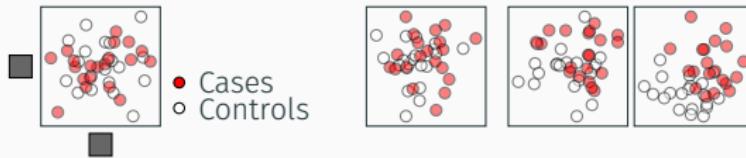
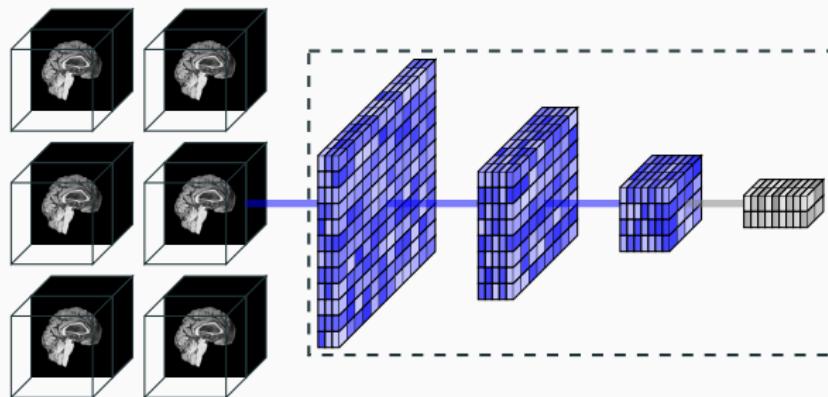
What does neural networks do?



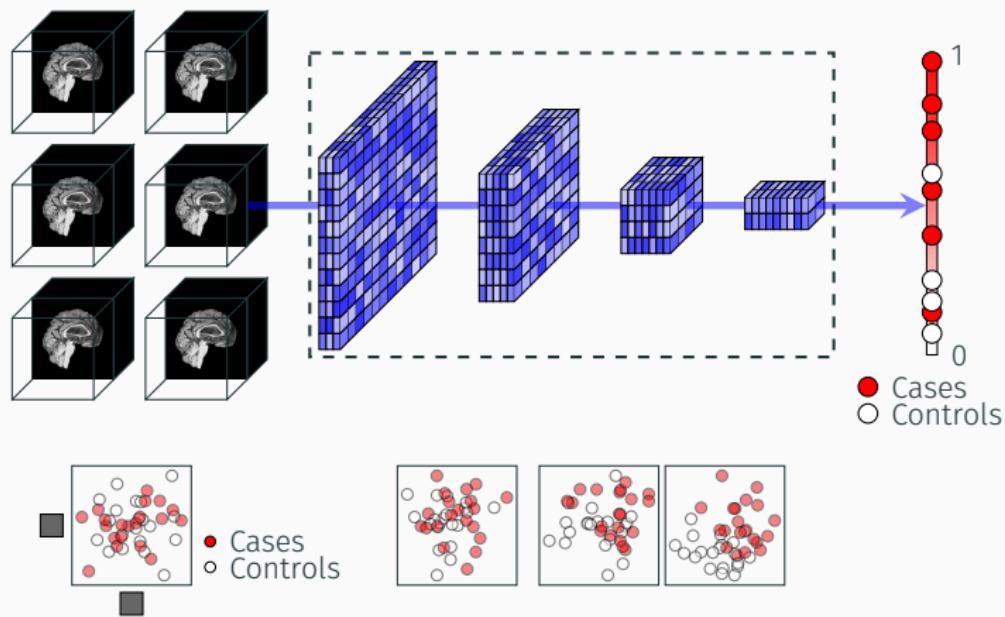
What does neural networks do?



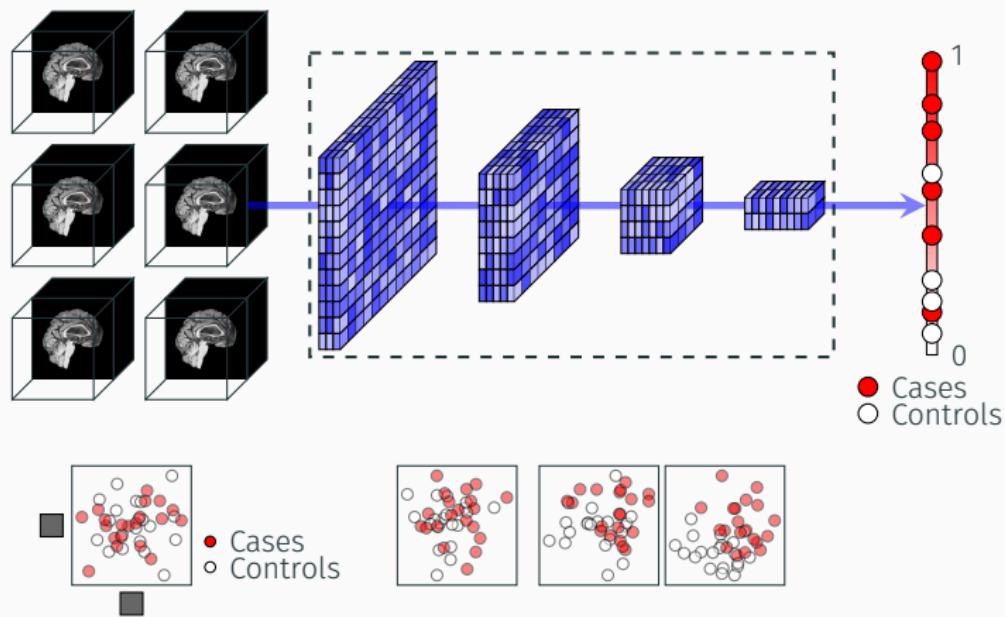
What does neural networks do?



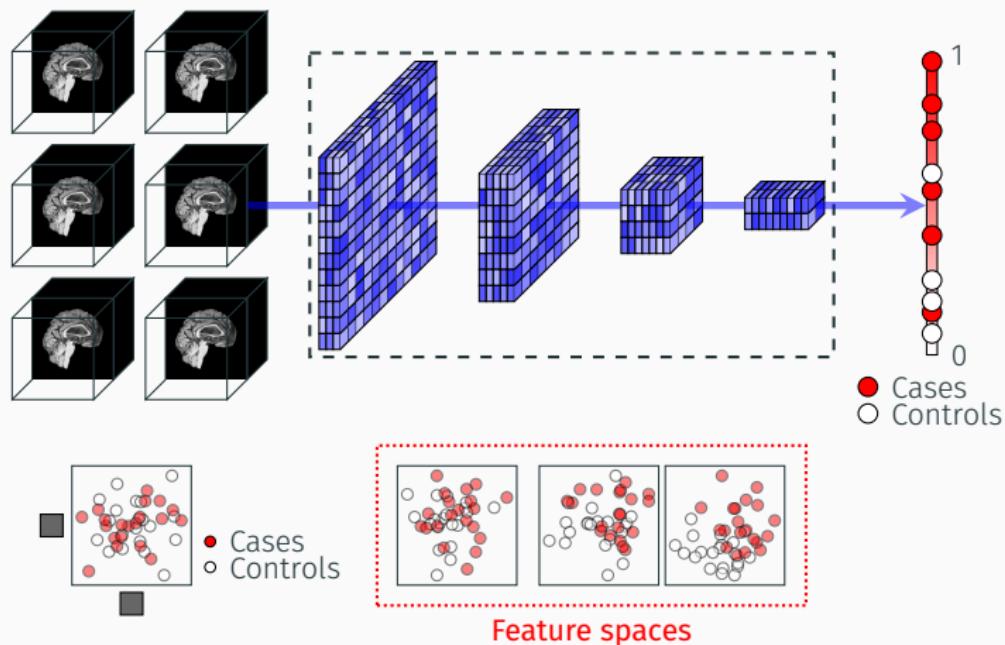
What does neural networks do?



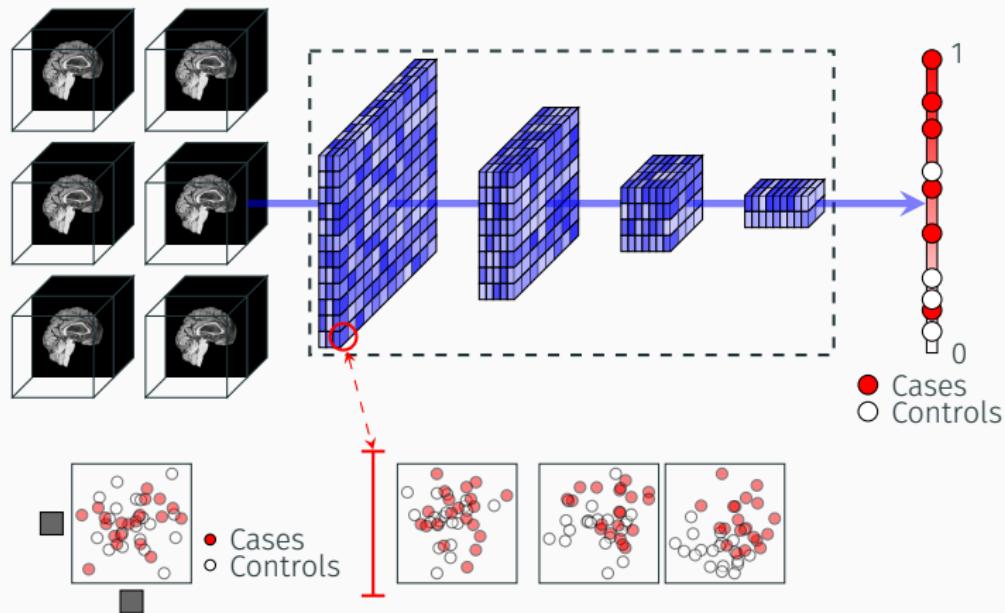
What does neural networks do?



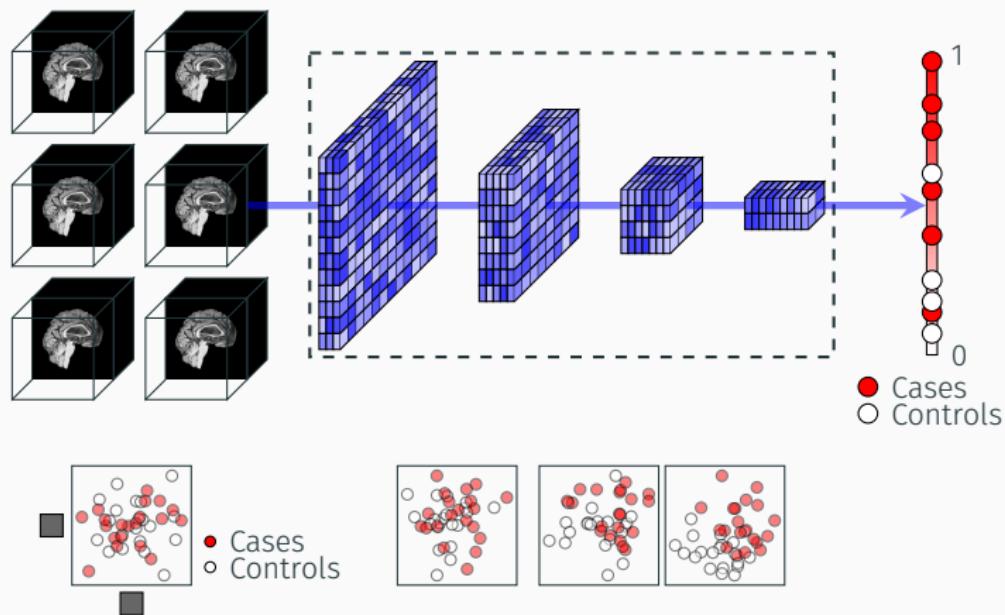
What does neural networks do?



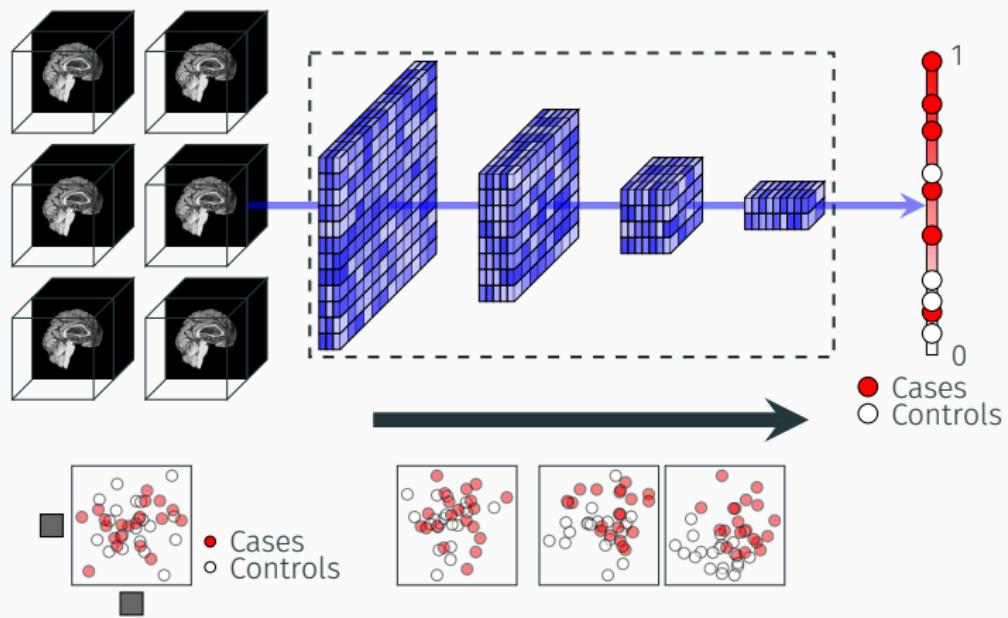
What does neural networks do?



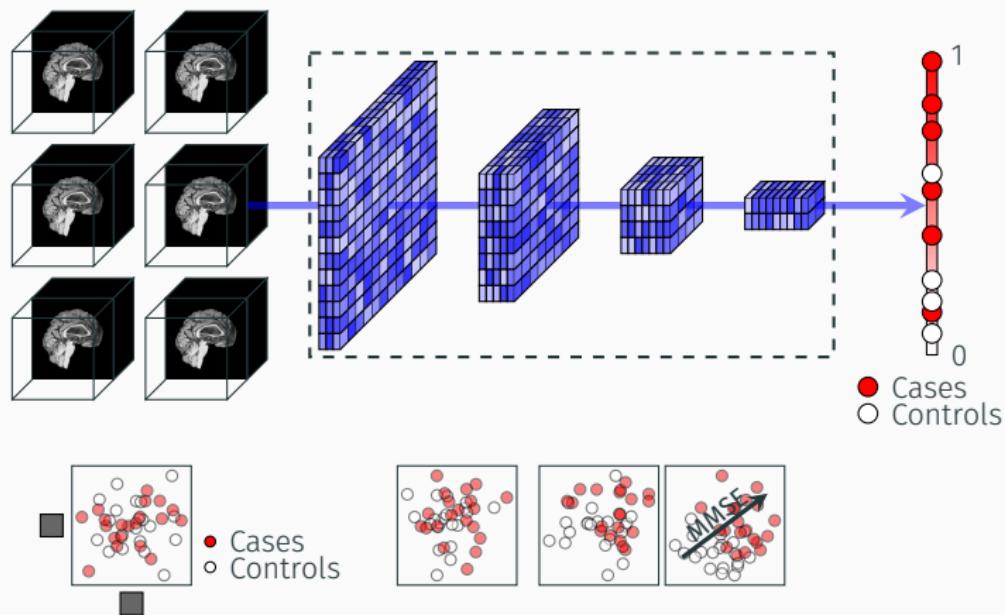
What does neural networks do?



What does neural networks do?



What does neural networks do?



How can we understand these features?



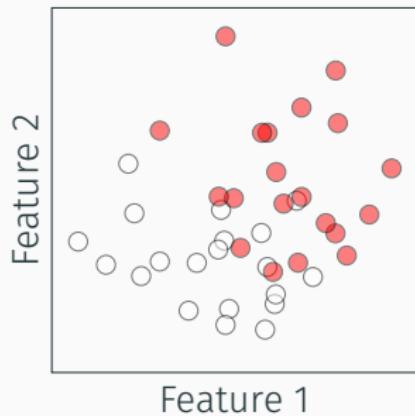
UNIVERSITY
OF OSLO

How can we understand these learned features?

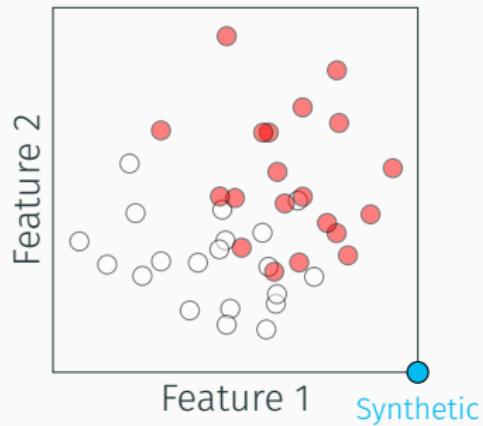
Explainable AI!



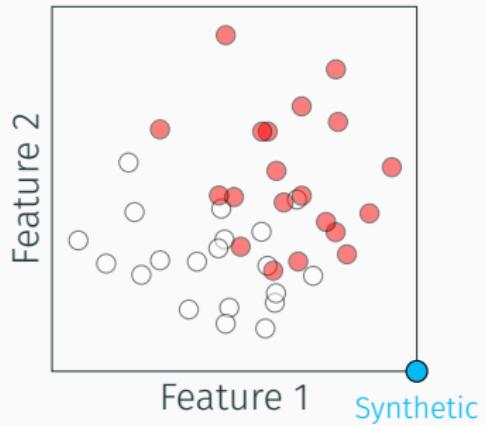
How can we understand these learned features?



How can we understand these learned features?



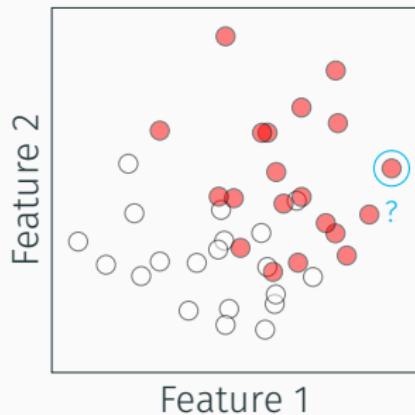
How can we understand these learned features?



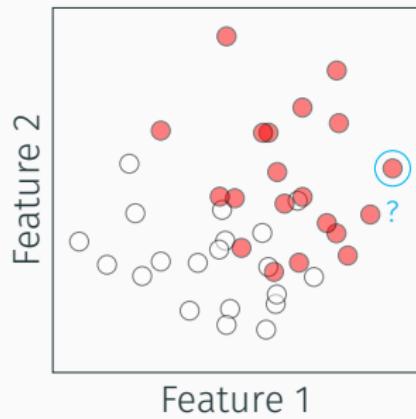
Activation maximization



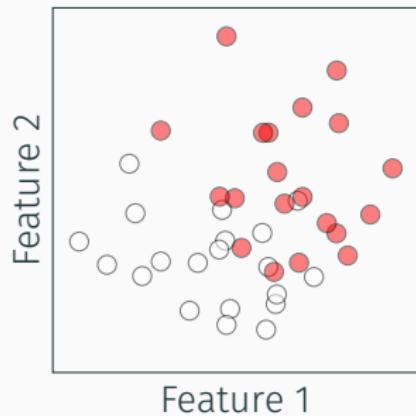
How can we understand these learned features?



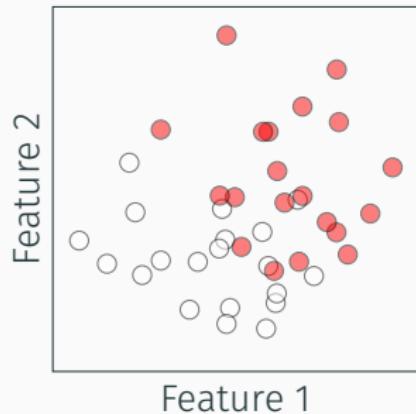
How can we understand these learned features?



How can we understand these learned features?



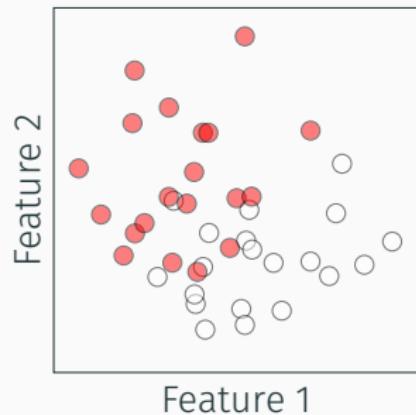
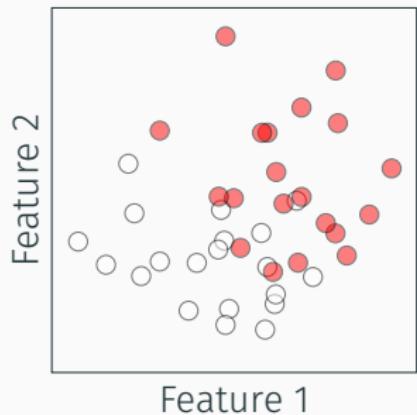
How can we understand these learned features?



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



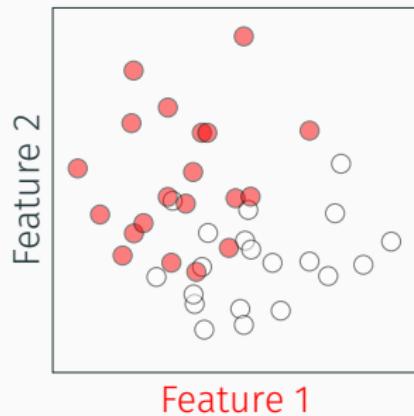
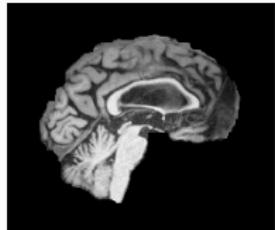
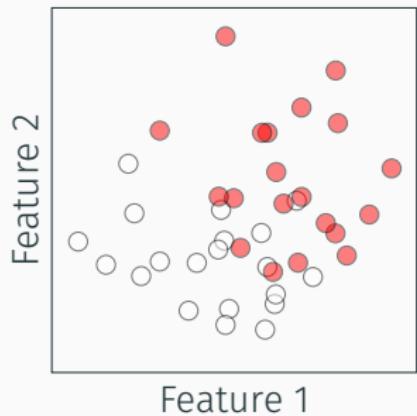
How can we understand these learned features?



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



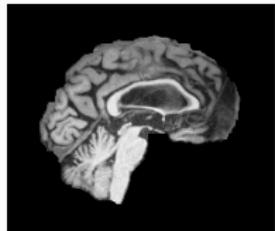
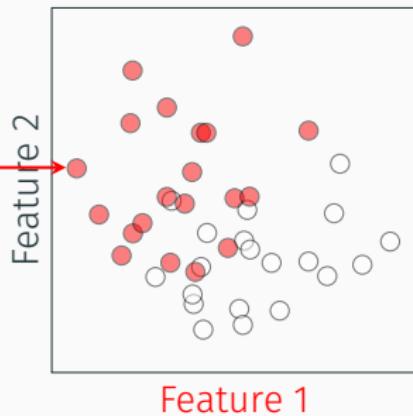
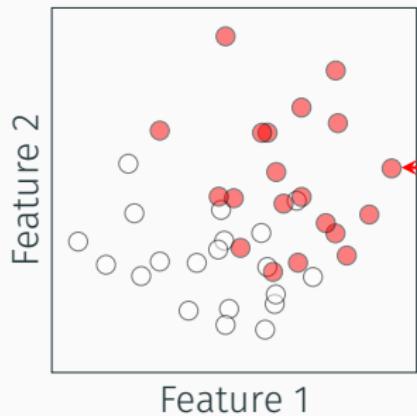
How can we understand these learned features?



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

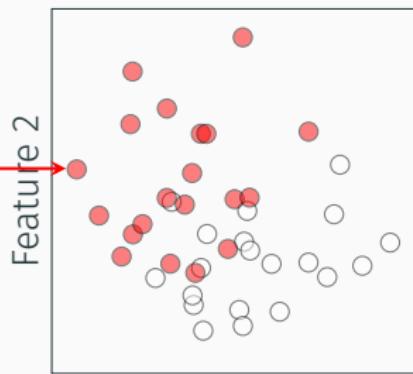
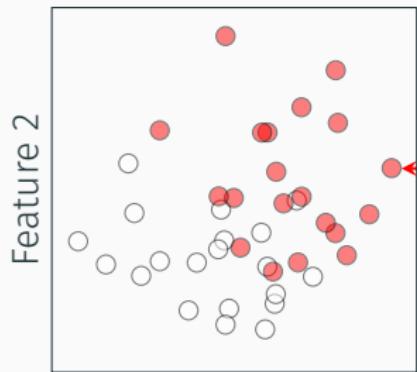


How can we understand these learned features?



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

How can we understand these learned features?



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

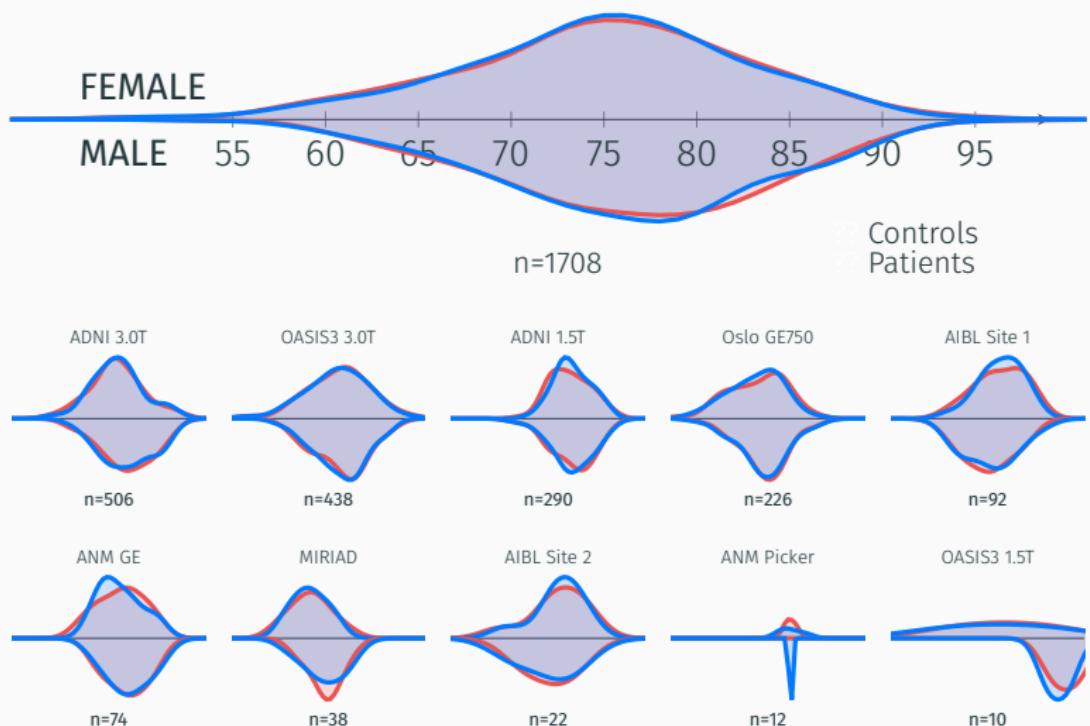


Use case: Dementia and XAI

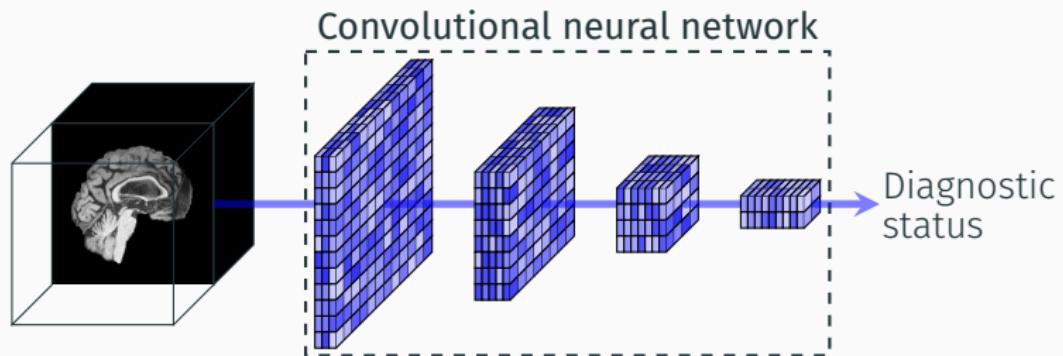


UNIVERSITY
OF OSLO

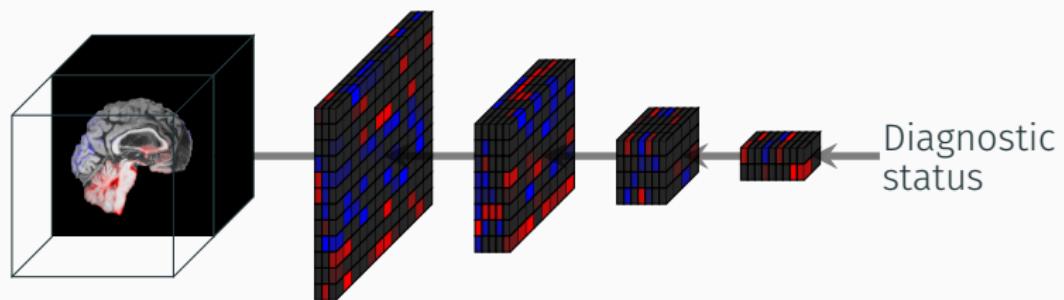
Dementia and explainable AI



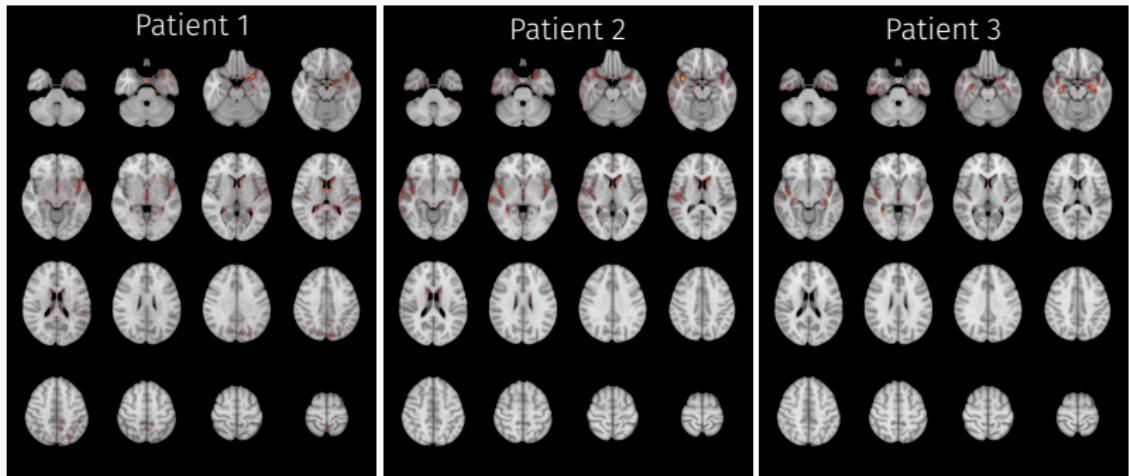
Dementia and explainable AI



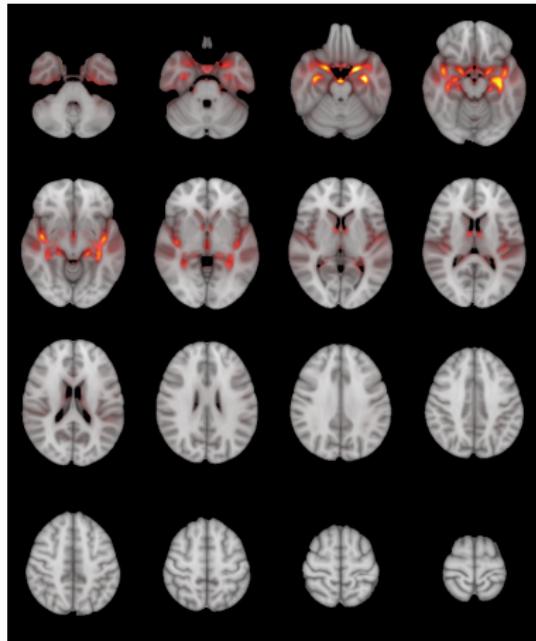
Dementia and explainable AI



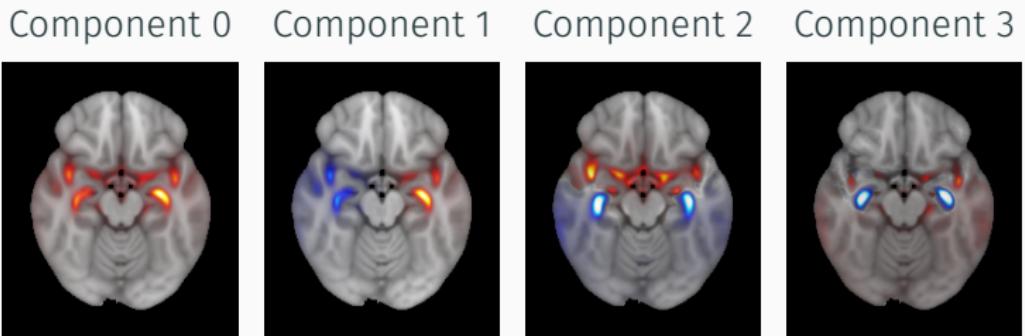
Dementia and explainable AI



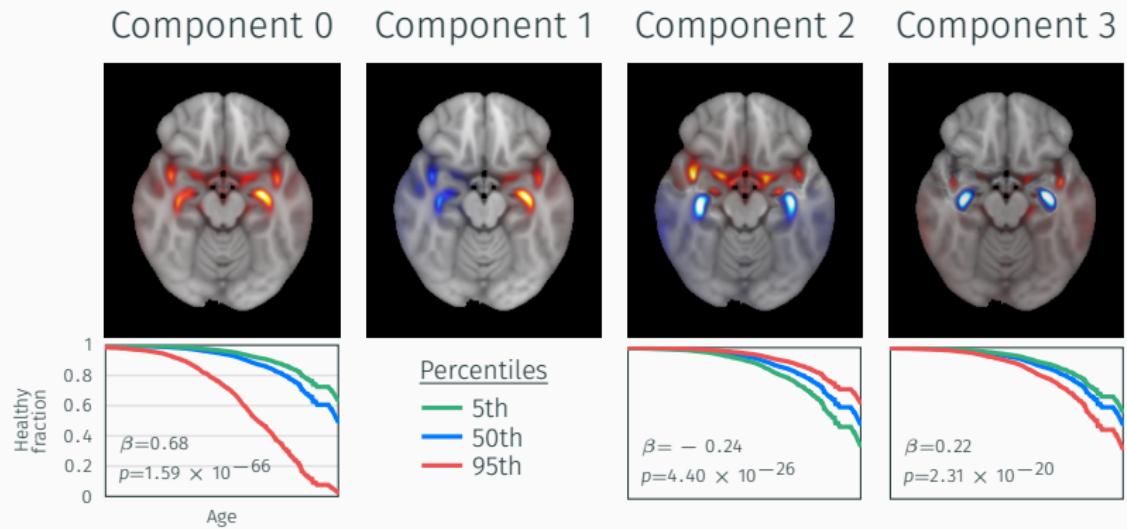
Dementia and explainable AI



Dementia and explainable AI

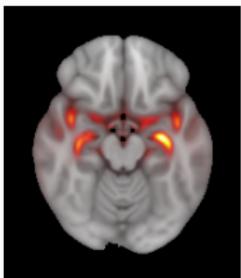


Dementia and explainable AI

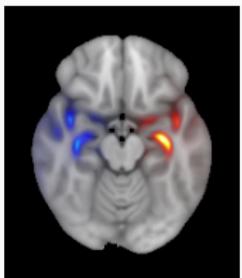


Dementia and explainable AI

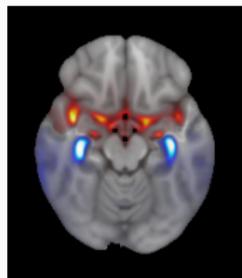
Component 0



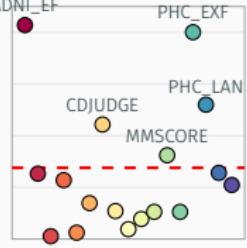
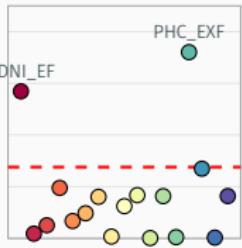
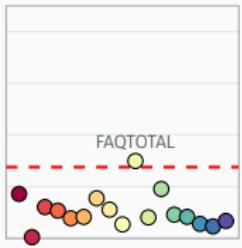
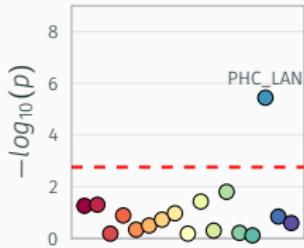
Component 1



Component 2



Component 3

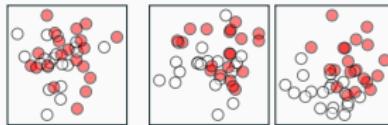
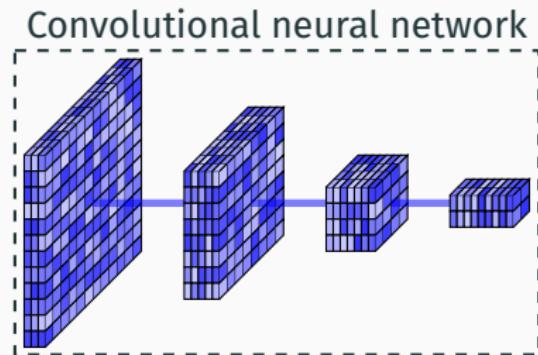


Multitask pretraining

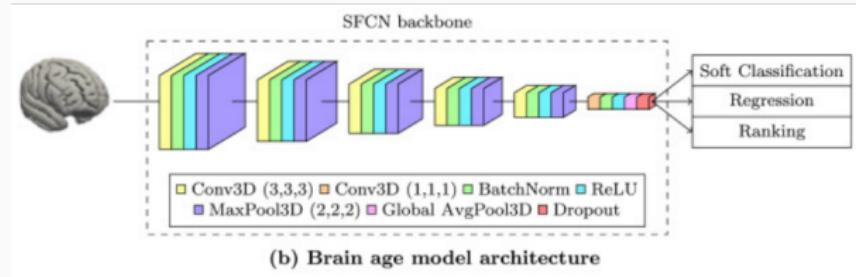


UNIVERSITY
OF OSLO

Multitask pretraining



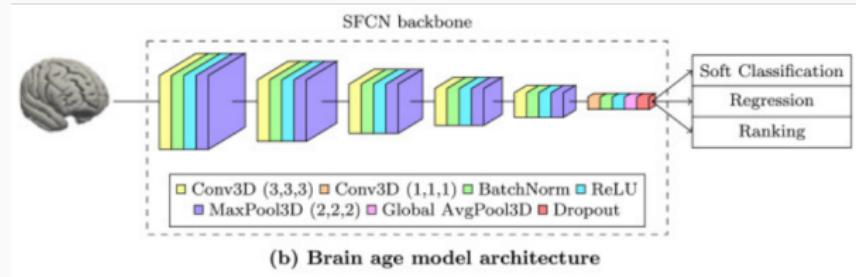
Multitask pretraining



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



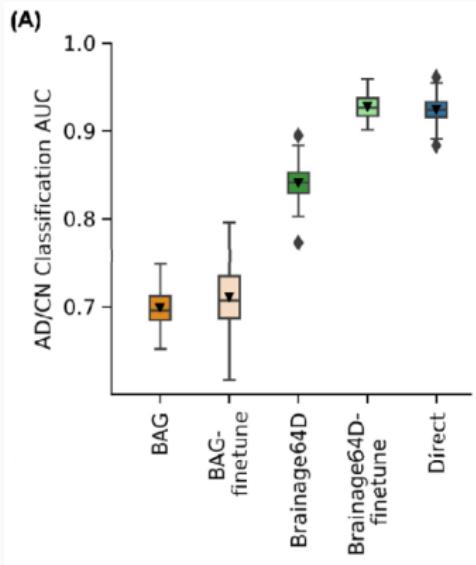
"Furthermore, we see this result as evidence that deep learning models trained to predict age in large multisite datasets constitute excellent starting points for transfer learning, which can subsequently be fine-tuned to a variety of tasks."

- 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.



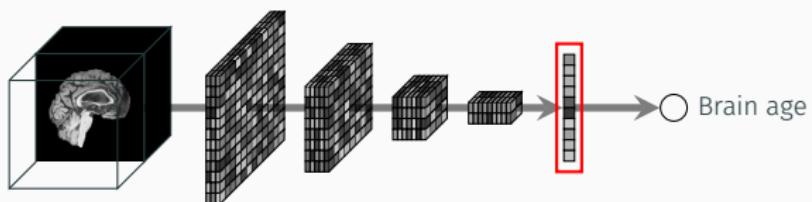
Multitask pretraining



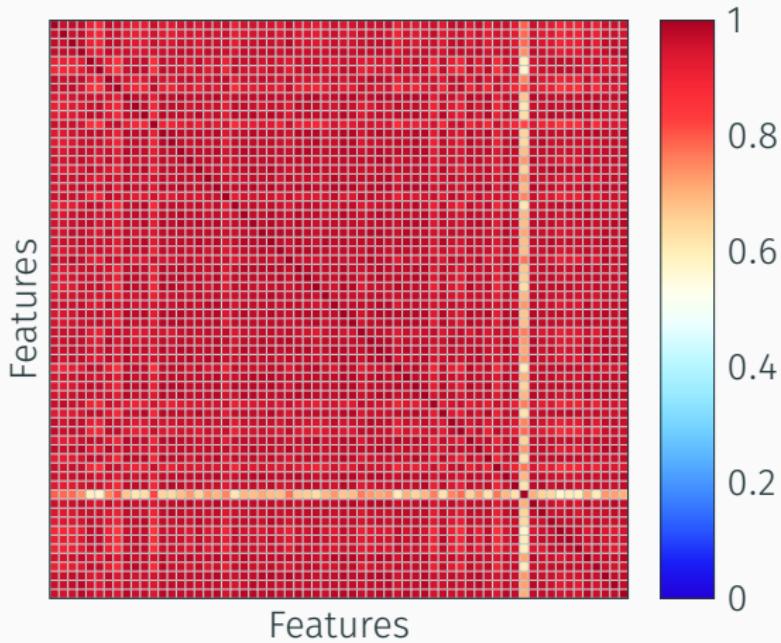
Tan, T. W. K., Nguyen, K. N., Zhang, C., Kong, R., Cheng, S. F., Ji, F., ... & B. T. Thomas Yeo. (2024). "Evaluation of Brain Age as a Specific Marker of Brain Health". *bioRxiv*, 2024-11.



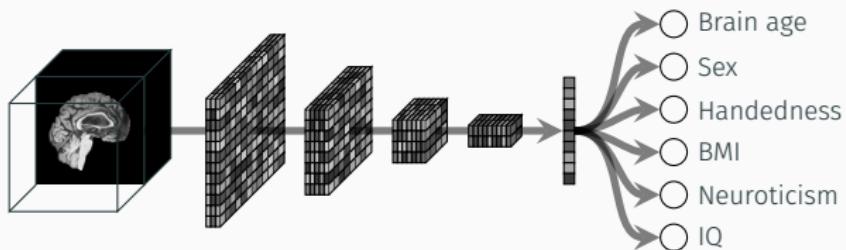
Multitask pretraining



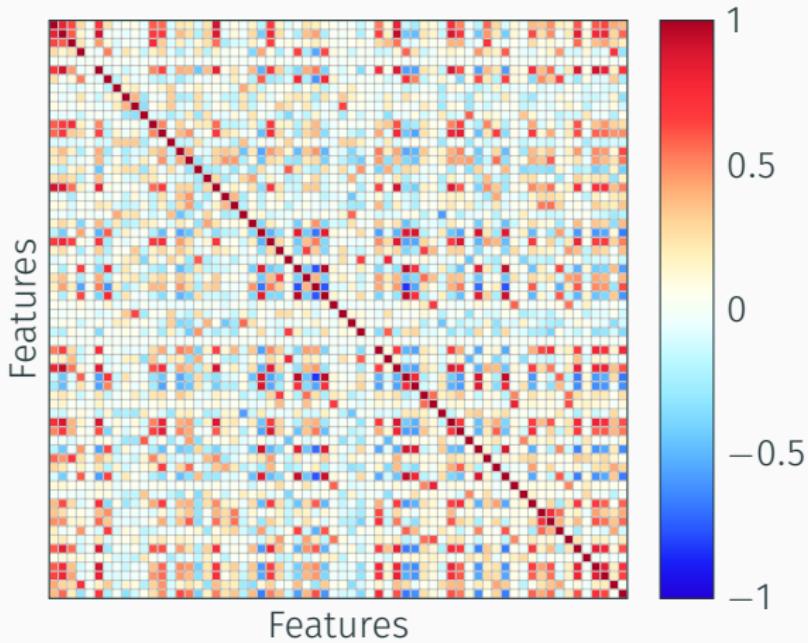
Multitask pretraining



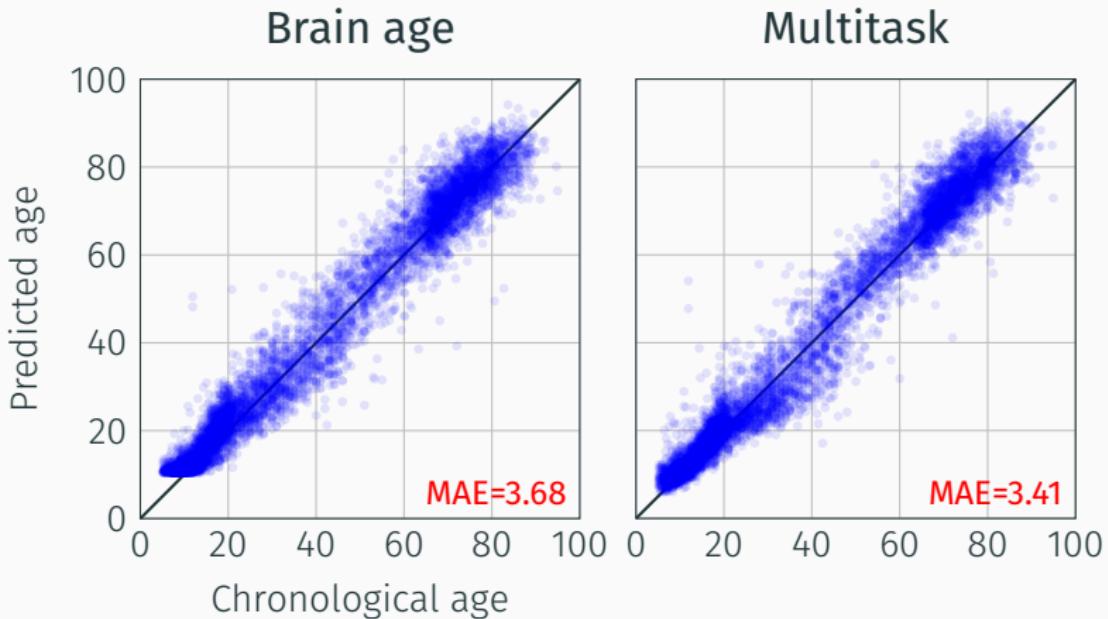
Multitask pretraining



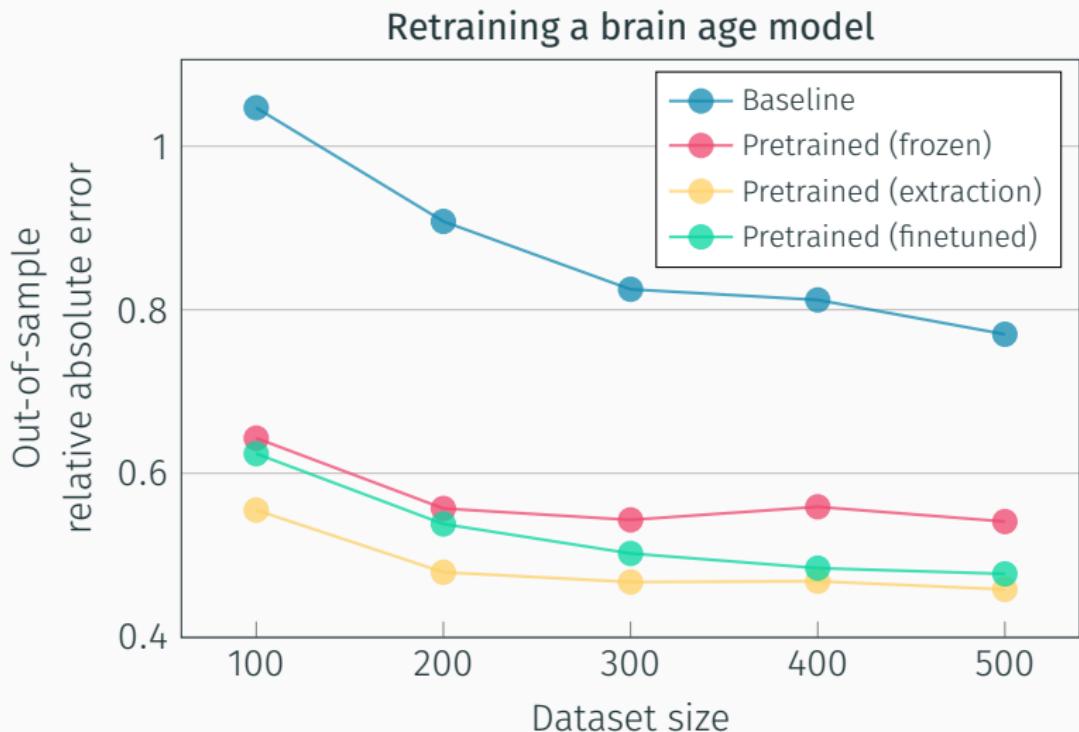
Multitask pretraining



Multitask pretraining

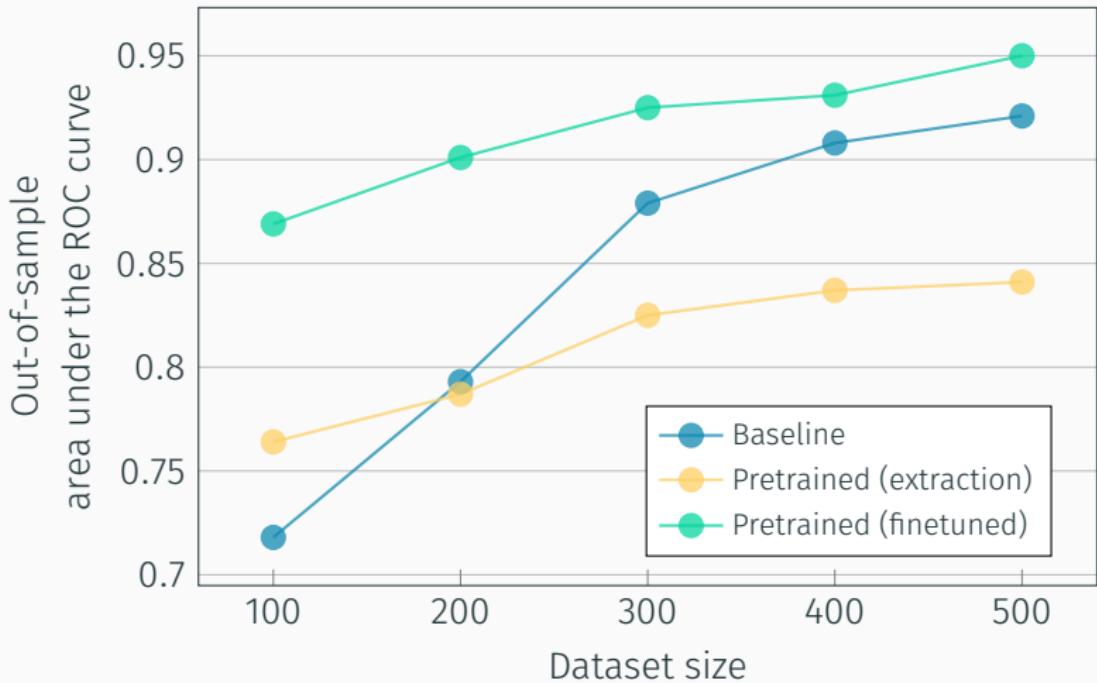


Multitask pretraining



Multitask pretraining

Retraining an AD classifier

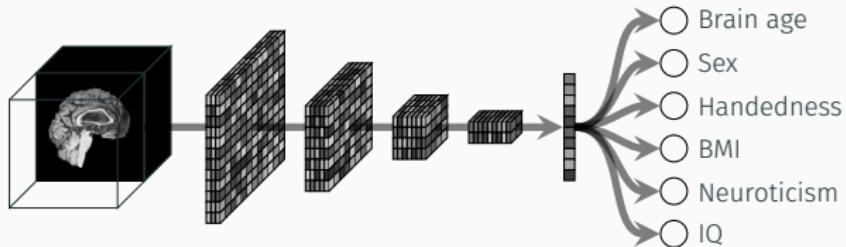


Use case: Explainable brain age

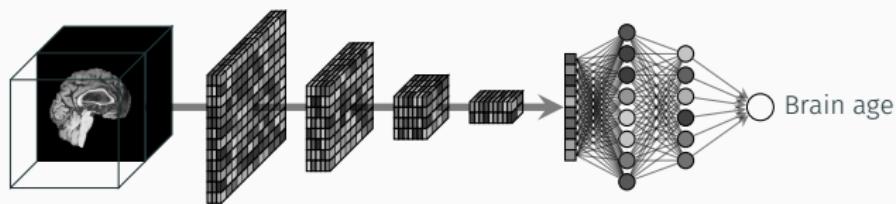


UNIVERSITY
OF OSLO

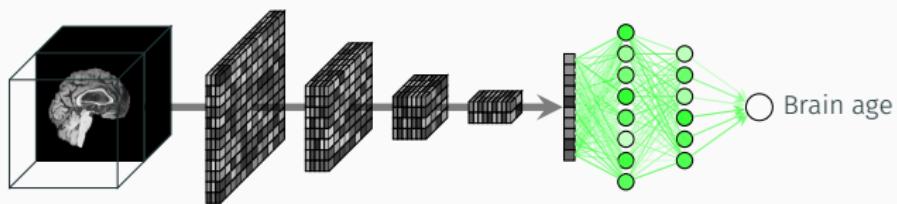
Explainable brain age predictions



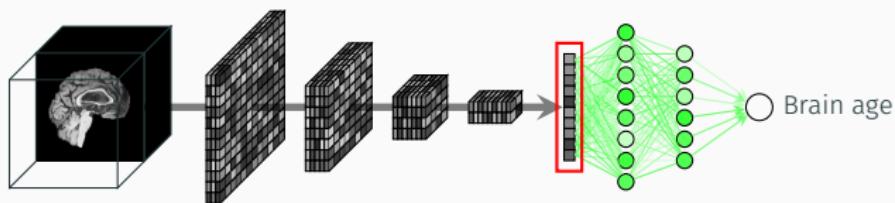
Explainable brain age predictions



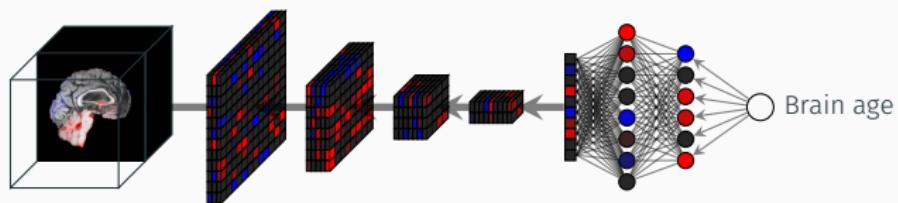
Explainable brain age predictions



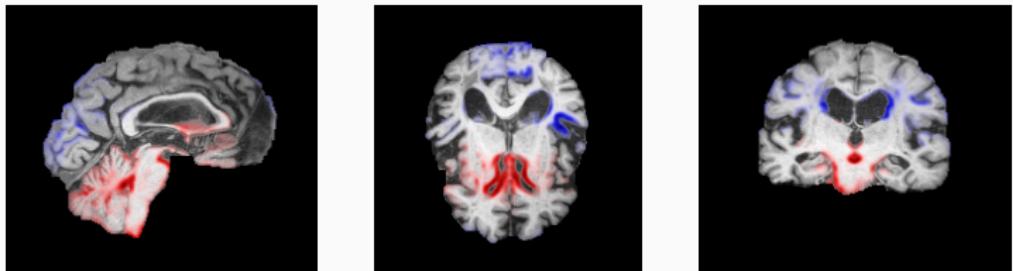
Explainable brain age predictions



Explainable brain age predictions



Explainable brain age predictions

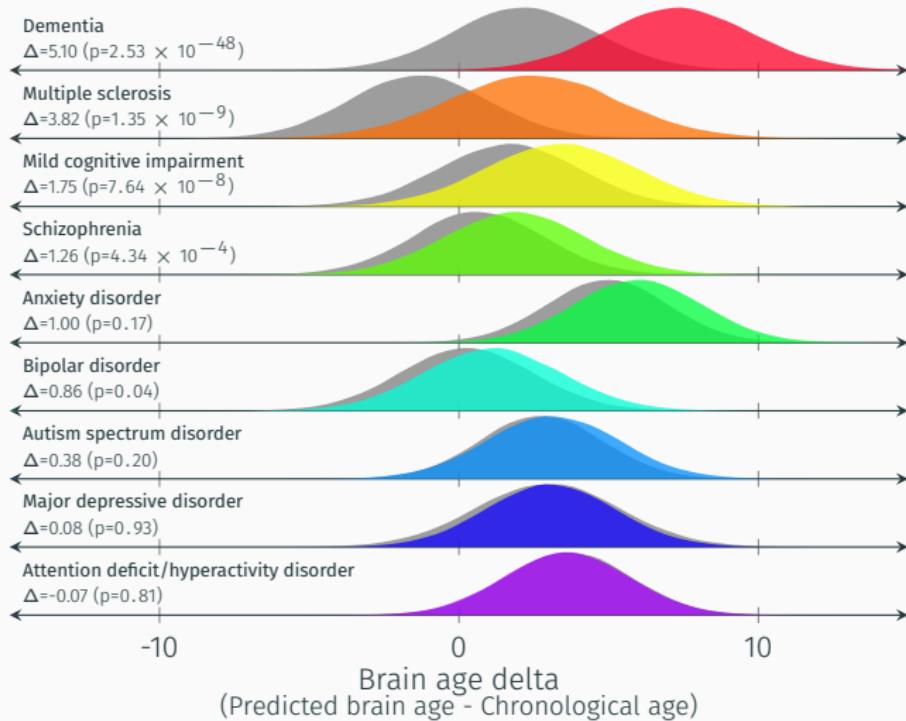


Younger
appearing

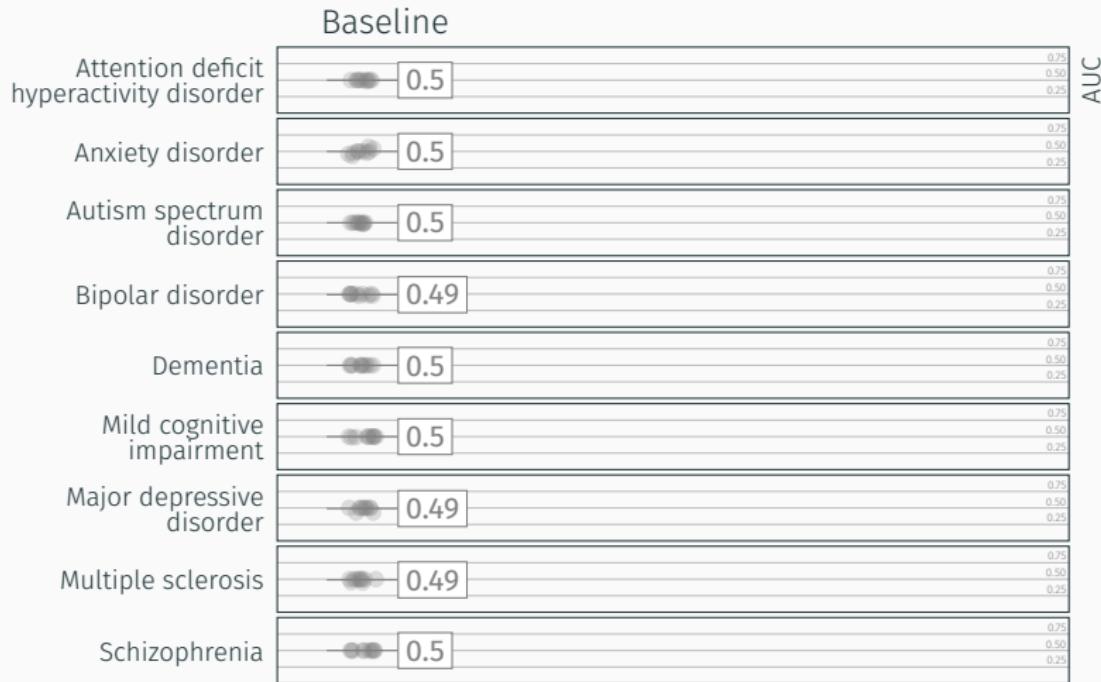
Older
appearing



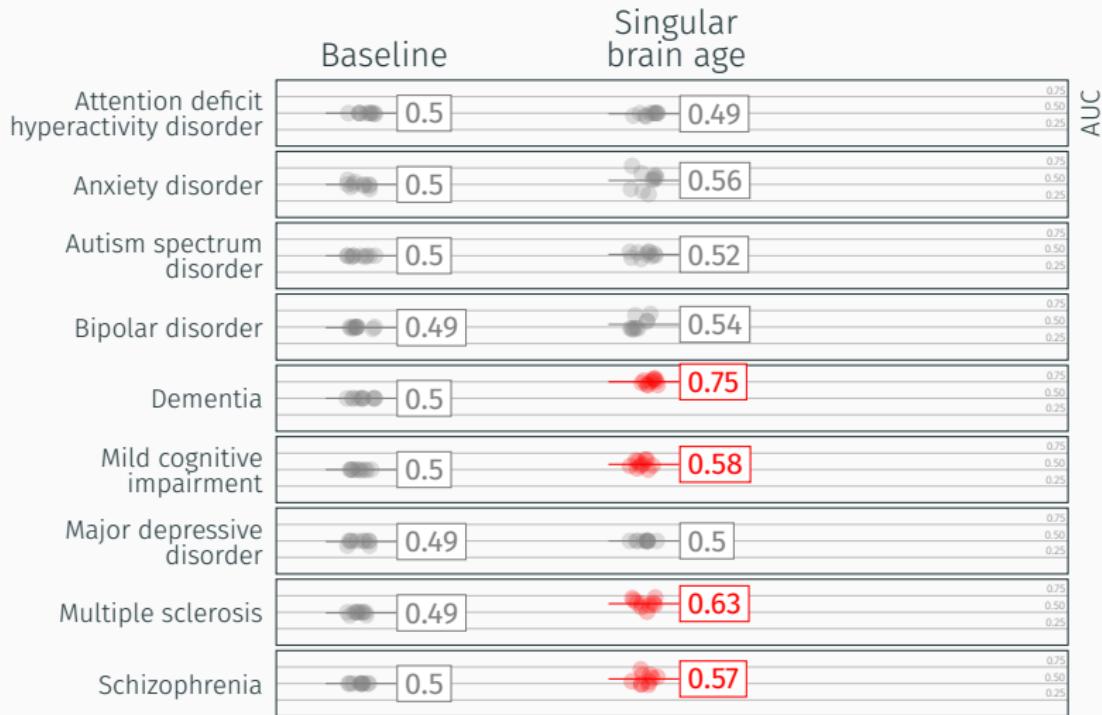
Explainable brain age predictions



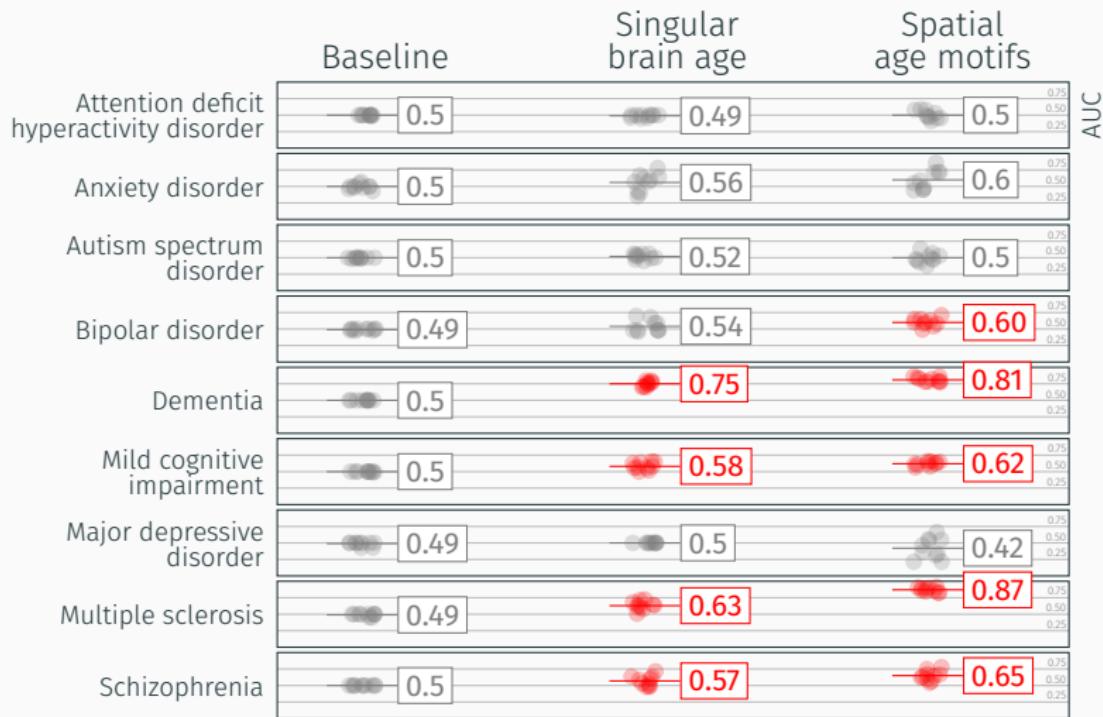
Explainable brain age predictions



Explainable brain age predictions



Explainable brain age predictions



Thank you!



UNIVERSITY
OF OSLO